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SMALL INSULATED FISH CONTAINERS

by

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PREPARATION OF THIS DOCUMENT

This paper has been prepared by the Fish Utilization and Marketing Service, Fishery Industries Division of FAO, with the aim to facilitate the planning and implementation of the use of insulated containers in small-scale fisheries. Dr C.D. Wood and Mr R.C. Cole of ODNRI, under contract with FAO, prepared the manuscript for this document based on an outline suggested by the Fish Utilization and Marketing Service of FAO. The users of this document are encouraged to offer possible comments on the paper and to supply new data on the use of insulated containers in small-scale fisheries, both at sea and in transport and marketing of fishery products on land, including for export.

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ABSTRACT

Small thermally insulated containers are very useful in enabling fish to be held chilled in an effective and economic manner. Although insulated containers would be particularly useful in less developed countries where ambient temperatures are often high, they are at present seldom used by the small-scale fisheries sector in such countries. Various commercial improvised and experimental insulated containers are, or have been, used. Their performance and background information on insulated containers design is reviewed. It is concluded that there is a need for further information and studies on insulated containers for small-scale developing fisheries and it is recommended that this work is conducted with a view to formulating extension programmes to widen their use.

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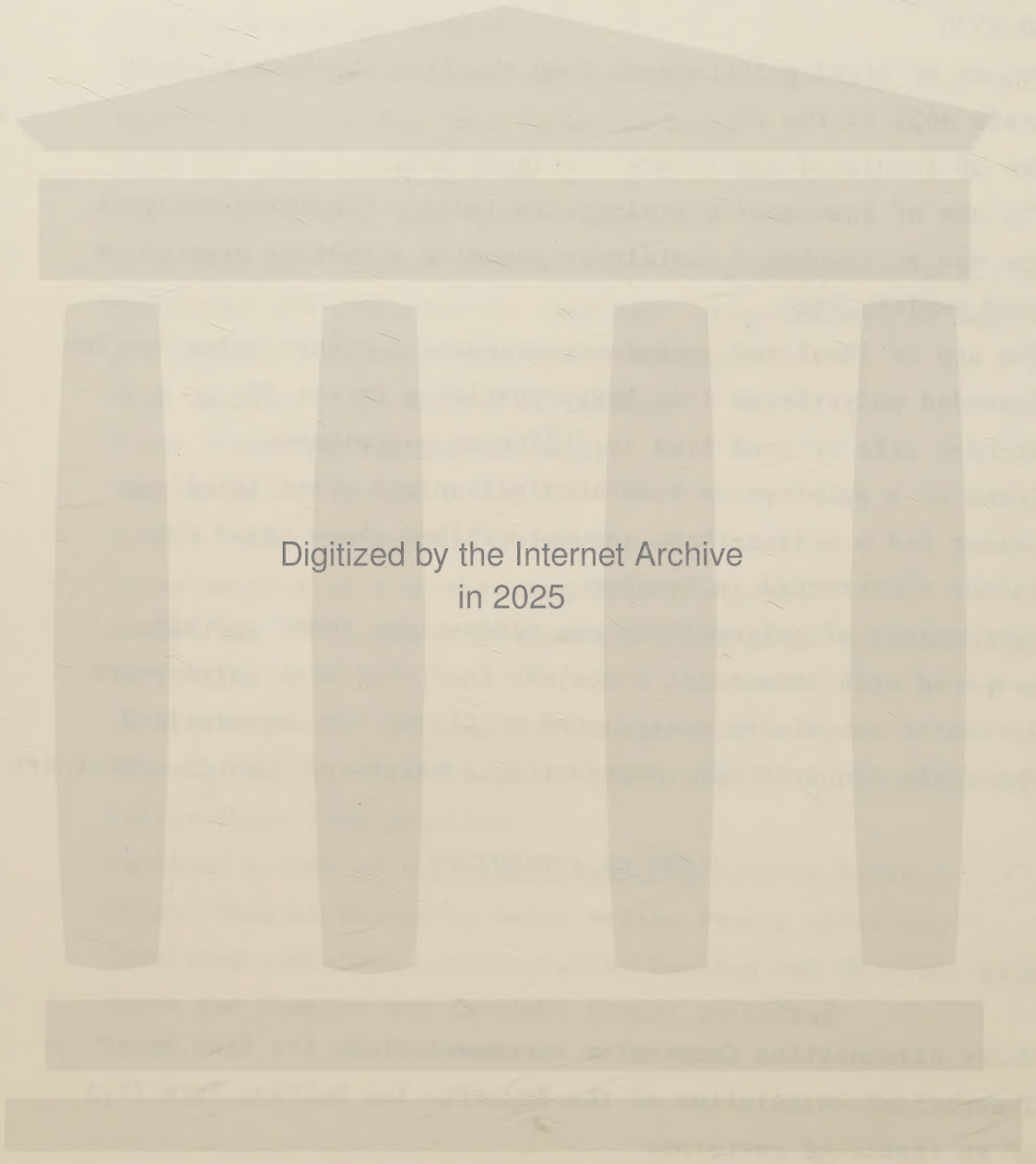

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1. INTRODUCTION

1.1 Purpose and scope of this document.

Containers are widely used in fish handling. Not only do they make handling easier, they also reduce the risk of the product being damaged. As chilling and freezing are important methods of conserving fish and fish products, thermal insulation plays an important role in effective handling. This role is widely appreciated in industrialised countries so it is paradoxical that in hot tropical countries, where it would be especially useful, thermal insulation is only rarely used in small-scale fisheries. The purpose of this document is to review the background and practical applications of insulated containers with a view to providing information of particular value to fisheries in the less developed countries.

After briefly reviewing methods of fish handling and the role of containers, the background to heat transfer and thermal insulation is considered. Economic factors are discussed, and examples are given of the use of insulated fish containers in both industrialised and less developed countries. Conclusions are drawn from information reviewed. It is not intended to give an in-depth description of every aspect of this subject, but the reader will be directed to relevant information sources where appropriate.

1.2 Why fish is chilled

1.2.1 The spoilage of fresh fish

Spoilage begins immediately a fish dies, when certain irreversible changes begin to take place. Within a few hours, the muscles gradually harden and the body becomes stiff. A fish may remain in this rigid state for a period of hours or days, depending on a number of factors, one of which is temperature. The muscles then relax and become pliable again. Stiffening is brought about because some of the chemical processes which take place in living organisms continue after death. One such process is muscle contraction which gives the characteristic hardness and rigidity until the chemical energy stored in the muscles is used up and the contraction ceases as the muscle degenerates. The process is known as rigor mortis.

While rigor mortis is a very obvious process other less easily observed events also occur. The digestive processes of the fish carry on resulting in the partial breakdown of the flesh. This is most apparent in the gut area and can give rise to the softening and bursting of the belly particularly in fish such as sardine and herring. Spoilage, the process by which the fish becomes stale and then bad, is due to this breakdown of the fish flesh (called autolysis) and the action of bacteria.

Bacteria are micro-organisms. As with other forms of life they must feed to grow and reproduce. The bacteria important in fish spoilage are able to digest substances in the flesh, giving rise to break down products which give bad quality fish its characteristic off odours and flavours. Although it is largely bacterial action which gives rise to off odours and flavours, the damage done by autolysis accelerates the rate at which the bacteria attack and spoil the fish. The mechanisms of fish spoilage are considered in more detail in Connell (1975), Aitken and et al (1982), Clucas (1981) and elsewhere.

1.2.2 The effect of chilling on spoilage

The spoilage processes are affected by temperature; the cooler the fish the more slowly it will spoil. At very low temperatures, when the fish is frozen, the normal spoilage processes described earlier are stopped (see FAO, 1974; Connell, 1975; Clucas, 1981; Aitken et al, 1982 for a more detailed description). While freezing is a popular method for the longer time preservation of fish it is generally undesirable for short term conservation. Slow freezing causes textural damage to fish and should be avoided. Ideally, chilled fish should be held as cold as possible without freezing it, which in practice means at a temperature of 0°C or slightly less. Below -1°C fish starts to freeze, resulting in complex physical changes.

Chilled fish can be kept in a fresh, acceptable condition for several days or even weeks if well handled. Figure 1 illustrates the effect of temperature on the keeping characteristics of a lean white fleshed fish, cod. This fish can be kept in an edible condition for up to about 15 days in ice, but will keep for only six days at 5°C (refrigerator temperature), 1-2 days at 15°C. At tropical temperatures most fish will spoil in about 12 hours, some in as little as eight hours. Tropical fish on ice has a longer storage life than similar fish from cold waters.

1.2.3 Keeping fish at ambient tropical temperatures can lead to food poisoning

Keeping fish at high temperatures not only leads to rapid spoilage; for certain species of fish the action of bacteria can result in the formation and accumulation of poisonous substances. This is a potential problem with many of the marine pelagic species such as sardine, mackerel and tuna. Toxicity is caused by the bacterial conversion of histidine (a normally occurring and harmless component of the fish) into histamine (a substance which causes a variety of responses in the human body). High levels of histamine in fish have been implicated in cases of food poisoning with symptoms such as skin-rash, headache, nausea and vomiting. Figure 2 shows the rate of accumulation of histamine in the fish species dorado kept at 25-30°C. Below 20°C very little if any histamine is formed in dorado (Bostock et al, 1985). Low temperature storage is the single most important and practical method that can be applied to control histamine production in fish. While the details of the toxicity of histamine are not well understood, high levels of this substance will result in the rejection of the fish in many countries.

Of particular concern is the fact that fish can contain potentially toxic levels of histamine while still appearing to be acceptable when judged by normal inspection methods. Chemical analysis can detect fish with significant levels of histamine. Fortunately this only seems to be a problem with fish kept at warm ambient temperatures, chilled or iced fish does not suffer from histamine formation. Therefore, good handling practices from capture to consumption will ensure that this problem is completely avoided. Conversely poor handling at any stage of distribution could lead to serious quality problems. A more detailed consideration of this topic is given by Arnold and Brown (1978).

1.3 Use of ice to chill fish

Ice has proved to be a very popular and indeed highly effective way of chilling fish and maintaining it at chill temperatures. The reason for this is that fresh water ice is an almost ideal medium for chilling fish. A more detailed description of the use of ice has been given by FAO (1974), Clucas (1981) and elsewhere, but its most important characteristics are considered below.

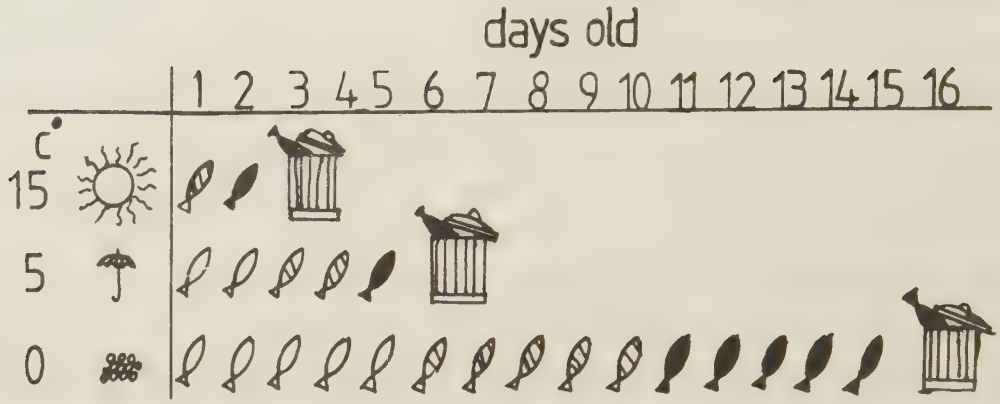


Figure 1 The effect of temperature on the spoilage of cod (a lean cold water marine fish)
Source: FAO, 1974

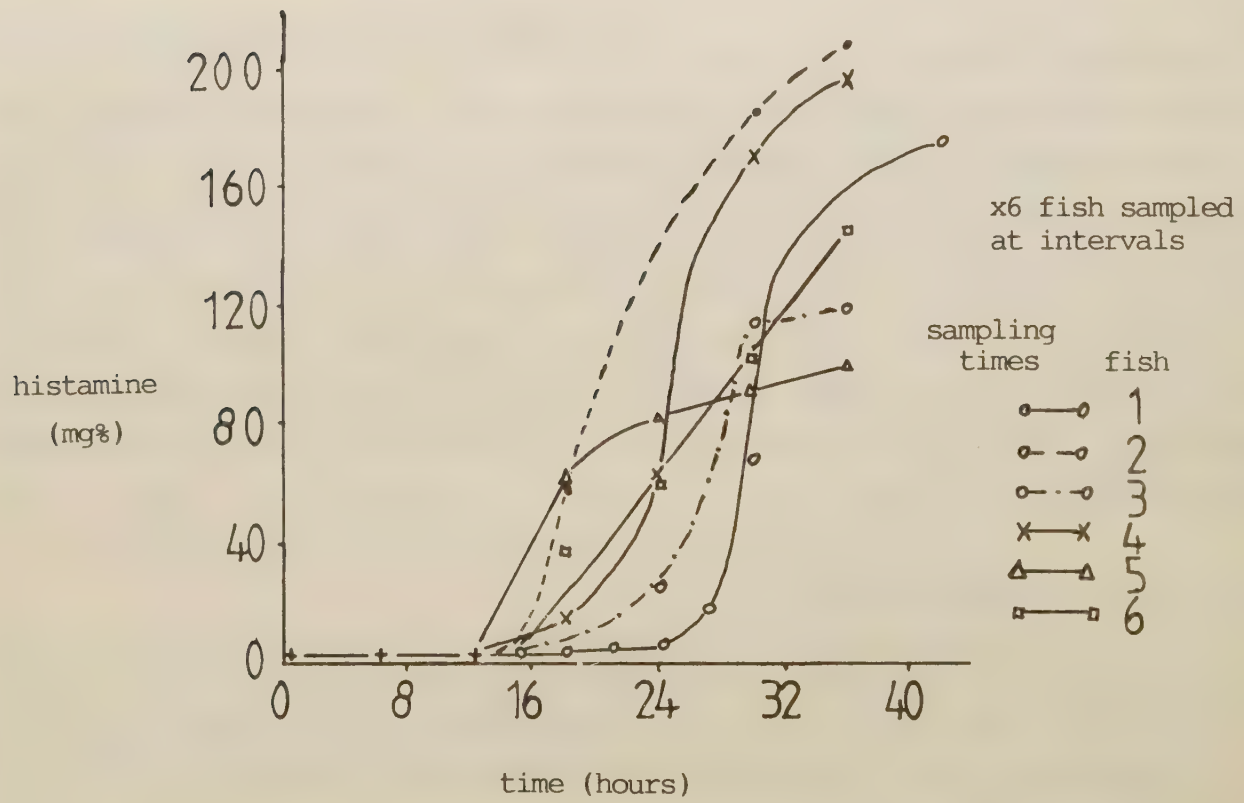


Figure 2 Accumulation of histamine in dorado (Mahi-mahi, Coryphaena hippuros) kept at 25° - 30°C
Source: Bostock et al, 1985

- Ice has a large cooling capacity for a given weight (to cool 10 kg of fish from 25°C to 0°C only about 3 kg of ice are required)
- Ice is harmless (assuming the water used to make the ice is of potable quality)
- Ice is comparatively cheap.
- Ice can cool fish quickly through intimate contact.
- Ice cannot freeze the product but maintains it at 0°C.
- Ice keeps the fish moist, washing its surface as the ice melts.
- Ice is transportable and can be used with minimal facilities.

In Section 3 some of the properties of ice and of iced fish will be considered where these relate to the use of thermal insulation. Suffice it to say that, except in certain situations where mechanically refrigerated sea-water (RSW) cooling systems are used, ice or iced (chilled) sea-water (CSW) have become the usual method for the short-term conservation of fresh fish. For this reason this document will concentrate on iced fish handling, although thermal insulation is important for the efficient use of chilling systems in general.

1.4 Frozen fish

For longer term conservation fish can be frozen and stored cold, a temperature of -30°C being recommended for the extended storage of most fish products. Freezing conserves many of the characteristics of the fresh product and for this reason has become the most widely used and versatile method of fish preservation, particularly in industrialised countries. For a description of the freezing process see FAO (1977), Clucas (1981), Aitken et al (1982); several other texts also exist. While large, technically sophisticated equipment is usually used for the distribution of frozen products, small insulated containers can play an important role where these facilities are not available, e.g.. for air freight of frozen products.

2. CONTAINERS FOR FISH

2.1 Advantages of using containers

Before considering in detail the process of chilling and the specific advantages of thermally insulated containers, it is worth considering the role and design of fish containers in general. Again other reviews do exist on this topic such as Brox (1984), Clucas and Whitehead (1986).

The major functions of a container are to make handling easier and protect the product. The use of containers reduces the number of times the product has to be handled thus reducing the risk of physical damage which, in the case of fresh fish, accelerates spoilage. Some degree of physical protection is given should the product be mishandled. It is now generally accepted that for maintaining fish quality the use of containers has advantages over bulk storage, firstly because it is easier to ensure good contact between the fish and the ice, and secondly because fish handling is minimised (Clucas and Whitehead, 1986). Purpose designed and cosntructed fish boxes are now widely used in industrialised countries while a wide variety of containers are used in developing countries. Insulated containers should fulfill the general design requirements for fish containers as well as having good thermal properties.

2.2 Requirements for fish containers

2.2.1 General requirements

Clucas and Whitehead (1986) have given the following as the most important requirements for fish containers.

- They must be of a suitable size for the range of fish to be handled or the products to be put into them.
- They should be of a convenient size for man-handling or lifting by mechanical equipment.
- They should be able to be stacked securely so that the weight of the containers on top comes onto the containers underneath not onto the fish underneath.
- They should be constructed of impervious non-tainting materials.
- They should be easily cleaned.
- They should provide drainage for the outlet of ice melt-water.

Additionally they should be adequately insulated or used in insulated or chilled rooms if not insulated. The Recommended International Code of Practice for Fresh Fish (Codex Alimentarius Commission, 1976) gives various recommendations for design and use of fish boxes for iced fish at sea and ashore. Some of these are included in Appendix 1.

2.2.2 Size and shape of fish containers

Clearly the most fundamental requirement for a container is that it is of the correct size and shape for its purpose. The fish must enter the container without being bent as this will damage the product. The container should also be big enough so that an adequate amount of ice can be mixed with the fish; an ice to fish ratio of about 1:1 is commonly used in tropical countries for packing fish and ice.

Small pelagic fish such as herrings, sardines, anchovies etc are very delicate and can be easily damaged if they are subjected to excessive pressure; white fish are generally tougher than small pelagic fish but they can still be damaged by undue pressure. As an approximate guide, the maximum depth of fish in a container should not be more than 60 cm for white fish, 40 cm for pelagic or fatty fish and 20 cm for fish fillets (Clucas and Whitehead, 1986).

If containers are intended for use in a fish hold of a specific boat or type of boat (or other transport system), their dimensions should be such as to make efficient use of the space available. Another consideration influencing size is the handling method to be used. One man can handle a maximum weight of perhaps 30 kg and 2 men can easily manage a 50 kg container by hand. If barrows, trollies, fork-lifts or other handling aids are to be used, boxes can be larger and heavier; but when unassisted manhandling is to be used, then maximum weights should not exceed 50 kg unless there are overriding factors which make this necessary.

2.2.3 Stacking and nesting

It is often very useful to have containers which can be stacked as shown in Figure 3, as this enables the available space to be used flexibly and efficiently. If containers are to be stacked it is essential that the containers themselves support the weight of the container above. If the contents support the weight considerable damage will be done to the product.

Some containers can also nest, that is when empty the bottom of one container can slide into the top of the next to give a compact stack. This saves space when the empty containers are stored. Several designs of fish boxes which can stack and nest have been developed. In small scale fisheries, where the number of con-

tainers in use in any given boat or lorry may be very limited, these two characteristics may be of lesser importance.

2.2.4 Cleanable, non-toxic and non-tainting materials should be used

As bacteria are largely responsible for fish spoilage it is essential to handle fish under hygienic conditions so as not to contaminate the product with greater numbers of bacteria. Containers should therefore be easy to wash clean if they are to be used more than once, which in practice means that the surface materials should be impervious to water. For this reason plastics have become increasingly popular in industrialised countries, largely replacing wooden boxes which are very difficult to clean.

Additionally materials which come in contact with fish must be non-toxic and must not taint the product. Particular care must be taken if steel is to be used as it must be protected from corrosion but lead based or other toxic anti-corrosion paints must be strictly avoided. Lead is highly toxic and should never come into contact with food. It is better to avoid materials which are susceptible to corrosion.

2.2.5 Drainage of ice-melt water

As fish is cooled and maintained at 0°C ice is melting continuously (see Section 3 for a detailed treatment of this topic). Also blood and drip (a mixture of water and fish protein) seeps from the fish. This mixture, which forms the melt water, is very attractive to bacteria. For this reason it is better if the melt water can drain away so that the product does not become immersed in dirty water. Clearly the melt water should not drain into the container beneath if the containers are to be used in stacks. It is, however, difficult to design a box which both nests and drains away from other boxes in the stack so that in many designs a choice is made between the two features.

Apart from a possible increase in the rate of spoilage, leaving fish in ice melt water results in the discolouration of the gills. Where gill colour is regarded as an over-ridingly important measure of freshness, as in parts of Eastern India (Clucas, in preparation) gill discolouration can lead to the rejection of fish which may otherwise be of acceptable quality.

2.3. Suitable designs of uninsulated fish containers

2.3.1 Fish containers used in industrialised countries

The perfect fish container for all purposes does not exist, but a range of designs have been developed in industrialised countries to cover most purposes. Fish boxes of many different designs are in general use. Two classes of fish box have been developed to suit different situations, returnable and non-returnable. Returnable boxes are used on-board fishing boats, at the landings and their wholesale markets, and in processing plants. They are characteristically durable and relatively expensive. Non-returnable boxes are used for distribution to wholesale and retain outlets where returning empty boxes would be expensive and difficult to organise. They are used just once and therefore must be cheap.

2.3.2 Returnable fish boxes

Returnable boxes were traditionally made of wood, but now plastics such as high density polyethylene (HDPE), low density polyethylene (LDPE) and polypropylene, and also aluminium, have become popular in industrialised countries. Each type has its specific advantages and disadvantages (reviewed by Brox, 1984; Clucas and Whitehead, 1986); but all are easy to clean which is the major reason why they have replaced wood as a box construction material. Standard box designs are generally not insulated and in fact aluminium is a good conductor of heat. The size, shape and design of the boxes varies depending on use and tradition and a considerable range of sizes exists inspite of some efforts to develop standards.

2.3.3 Non-returnable fish boxes

The general requirements for fish containers also apply to non-returnable boxes except that as they are only used once and then discarded, they do not necessarily have to be easily washable. They must, of course, keep the fish under hygienic conditions. Three major types are in commercial use at present, the wooden box (although this is of declining importance), the fibreboard box and the expanded polystyrene box. It is noteworthy that, unlike the other types of fish boxes in general use in industrialised countries, expanded polystyrene boxes have good thermal insulating properties. Wooden and fibreboard boxes have some insulation but can be lined with expanded polystyrene for additional insulation.

Wooden boxes are usually made from softwoods. Thin slats are fastened using wire nails and metal straps may be put round the filled box to strengthen it. Fibreboard is made from recycled newspapers, magazines, cardboard and indeed used fibreboard. It is a moderately strong material which can be coated to make it water resistant, but it has poor insulating properties. It has become popular principally because it makes hygienic and attractive boxes while being inexpensive and convenient to use. It is provided as flat ready creased sheets which can be turned into boxes very quickly. The shape is held using metal staples to hold the overlapping corners tabs. Brox (1984) describes various types of fibreboard box in more detail while Wignall (undated) has prepared a brief review of the subject. Boxes containing polystyrene are considered in more detail in Sections 6.3 and 6.4.

2.4 Uninsulated fish containers used in less developed countries

A wide variety of containers are used in the less developed countries, such as rounded baskets made of bamboo, cane or other plant fibres, wooden boxes, metal bowls or cardboard boxes if they happen to be available (see Subba Rao, 1965, for a review of containers used in the Indo-Pacific region). However, many of the types in use fall short of the basic requirements, particularly in the field of hygiene. Fibre baskets are virtually impossible to keep clean while the shortcomings of wooden boxes have been noted previously. Nevertheless, these containers do have two essential advantages, firstly they are locally available and secondly they are inexpensive. In many developing country situations these advantages will outweigh the disadvantages as far as the local trade is concerned. It is largely for these reasons that the containers now widely used in industrialised countries have not yet been adopted for general use in developing countries. Generally speaking, only in export orientated fisheries, where outside contacts and revenues make the importation of containers possible, have these more expensive handling systems been adopted.

3. ICE REQUIREMENTS FOR CHILLED FISH

3.1 Chilling fish in ice

Just as water runs downhill, heat passes from something at a high temperature to something at a low temperature. Heat passes from the fish to the ice and as a result the ice melts and the fish cools. Although this is apparently a simple enough process it is worthwhile considering some of the theoretical background.

Heat is a form of energy, so chilling (which is the trnasfer of heat away from an object) is a transfer of energy. When 1 kg of a substance is cooled by 1°Celsius (deg C) the amount of energy removed is called the Specific Heat of this particular substance. Every substance has a characteristic Specific Heat. Although the exact Specific Heat for fresh fish depends on its chemical composition ther are only minor variations between fatty and lean fish. A figure of 3.75 kJ/kg deg C can be taken as typical for wet fish where kJ signifies kilofoules, the unit of energy (or heat).

Using the Specific Heat it is possible to calculate how much heat must be extracted from a known weight of fish to produce a given degree of cooling. If we consider the example of cooling 10 kg of fish from 25°C to 0°C the concept be illustrated.

Amount of heat to be extracted (H_1) = $M_f \times C_{pf} \times (T_{f1} - T_{f2})$

where M_f = mass of fish to be chilled (in kg)

C_{pf} = specific heat of fish (kJ/kg deg C)

T_{f1} = temperature of fish before chilling (°C)

T_{f2} = temperature of fish after chilling (°C)

In the example $H_1 = 10 \times 3.75 \times 25 = 937.5$ kJ.

It is this heat energy of the fish that melts the ice. We must now consider how much ice is needed to extract 937.5 kJ of energy from the fish.

The amount of energy required to melt 1 kg of ice at 0°C is called the Latent Heat of Fusion of ice (L) and is 334 kJ/kg for fresh water ice. In other words 334 kJ of energy are required to melt 1 kg of ice at 0°C, converting it to water at 0°C. Hence by dividing the extracted heat (H) by the Latent Heat of Fusion (L) we will arrive at the weight (in kg) of ice which will melt in cooling the fish (M_1).

In general $M_1 = \frac{H_1}{L}$

and in this example $M_1 = \frac{937.5 \text{ kJ}}{334 \text{ kJ/kg}} = 2.8$ kg; 2.8 kg ice are required to chill 10 kg of fish from 25°C to 0°C.

This figure should only be taken as illustrative as not only are there variations in the Specific Heat of fish but more significantly there are usually other heat sources as well besides the fish, in particular if small quantities of fish are chilled. Furthermore, slushy ice may contain 10-20 percent water by

weight and thus in practice a greater weight of ice is required. Table 1 indicates the weight of ice needed to chill 10 kg of fish to 0°C from various starting temperatures. In order to reduce transport costs in fish marketing the fish could be pre-chilled before transport in insulated containers or trucks. In this way, little or no ice would need to be transported.

3.2 Maintaining the temperature of chilled fish

Not only should fish be chilled to 0°C, it should be maintained at this temperature. As we have stated earlier, heat moves from hot objects to cold ones. If iced fish at 0°C is in an environment which is hotter than this, for example in a tropical country where the temperature of the air can be 30°C or more, then heat will tend to travel towards the ice and fish. This entry of heat must be counteracted by the melting of additional quantities of ice in order to maintain a temperature of 0°C.

Thus the chilling of fish in ice is essentially a two stage process. Firstly ice is required to reduce the temperature of the fish and secondly ice is required to "absorb" heat entering from the outside environment.
Whereas in the first stage around 0.3 kg ice is required per kg of fish, the amount of ice required in the second stage depends primarily on ambient temperature, insulation and storage time.

3.3 Role of thermal insulation in reducing ice requirements

Thermal insulation reduces the rate at which heat can pass from the outside into the container. Insulation cannot affect the amount of ice which is required to reduce the temperature of the fish, only the amount of ice needed to maintain the fish at 0°C. In fact if it were possible (or even desirable) to make a perfectly insulated container ice would only be needed to chill fish and the amounts indicated in Table 1 would be sufficient. In practice it may be useful to use twice as much or more ice as the amounts given in Table 1, giving an idea of the practical importance of thermal insulation. It must, however, be noted that the continuous melting of ice keeps the fish moist and continually washes its surface removing some bacteria. It is therefore desirable to allow some heat entry. In tropical fisheries this is unlikely to be a consideration of practical significance as at such high ambient temperatures heat inevitably enters.

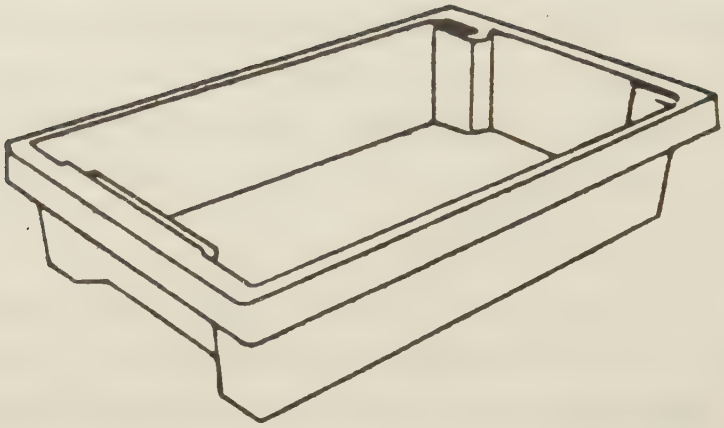
3.4 Types of ice

Various types of ice are available depending on the design of machine used to make it. Ice can be made from fresh water or sea water, although fresh water ice is generally recommended if there is an adequate water supply (FAO, 1974). Types of fresh water ice differ as to their physical characteristics, such as particle size and density. The fundamental thermal properties described earlier are exactly the same for any type of fresh water ice; the properties of sea water ice are slightly differrent and also depend on the amount of salt in the ice.

Different types of ice making equipment have been reviewed by FAO (1974), Clucas (1981). They can be divided into two basic types, block ice and small ice. Block ice is produced in large ice making machines which freeze water in large containers to give a block. The size of block varies depending on the machine but normally blocks weigh between 25 and 135 kg. Small ice comes in several forms from cubes and other small particles to very fine snow or powder ice.

The smaller the particle size of the ice, the greater its surface area and the lower its bulk density. Ice with a large surface area can absorb heat, and thus melt, quickly. It cools fish very rapidly as a very good contact is made between the fish and the fine ice particles. The rate at which a fish of any particular size and shape is chilled is related to the area of its skin (and belly cavity if gutted) in physical contact with ice. Unfortunately fine ice particles also make a good contact with the walls of the container and the air inside so that ice will also melt quickly by heat coming from the environment. Hence thermal insulation is particularly important when small ice is used, especially under tropical conditions where it would be lost very quickly in uninsulated containers.

Large ice blocks melt relatively slowly and for this and other reasons are popular in tropical countries. They can be distributed and stored as blocks with just sawdust or other simple insulators being used to keep losses at acceptable levels. The blocks must, however, be well broken before use on fish otherwise the ice will not be able to chill effectively. As regards thermal properties there should be little difference between fish and ice mixtures regardless of which type of ice is used. Small ice has a relatively low density. To give equal cooling effects equal weights of ice must be used, but the volume of small ice needed will be greater than the volume of crushed block ice (illustrated in Figure 4).



boxes nest when all are in the same direction, stack when alternate boxes are turned round (through 180 degrees)

Figure 3 Modern design of stacking and nesting plastic fish box

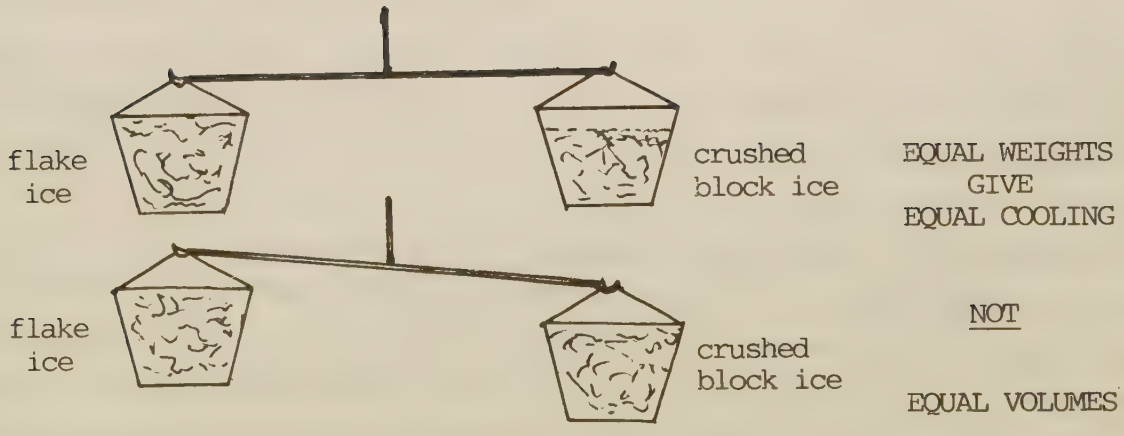


Figure 4 Equal weights of ice give equal cooling
Source: FAO, 1975

3.5 How ice is commonly mis-used

Unfortunately many people in the fisheries industry do not fully realize that ice has to melt to chill things. If large chunks of ice are in contact with parts of the fish it is often assumed that the fish is cool when in fact it is only being chilled slowly. The mere presence of ice is wrongly assumed to be sufficient to ensure that the product is well conserved.

If thermal insulation is not used, then the ice can melt very quickly, particularly at ambient tropical temperatures. There is a tendency to use large fragments of block ice rather than well broken ice because large fragments melt more slowly. For similar reasons there can be some prejudice against small ice as it melts quickly and is considered not to have the same ability to chill fish, although in fact rapid melting is indicative of its ability to chill quickly. The concepts are illustrated in Figure 5. It is the author's belief that ice will continue to be widely misused in tropical fisheries until adequate levels of thermal insulation are used and that fish quality will continue to suffer as a result.

4. HEAT TRANSFER AND THERMAL INSULATION

4.1 Mechanisms of heat transfer

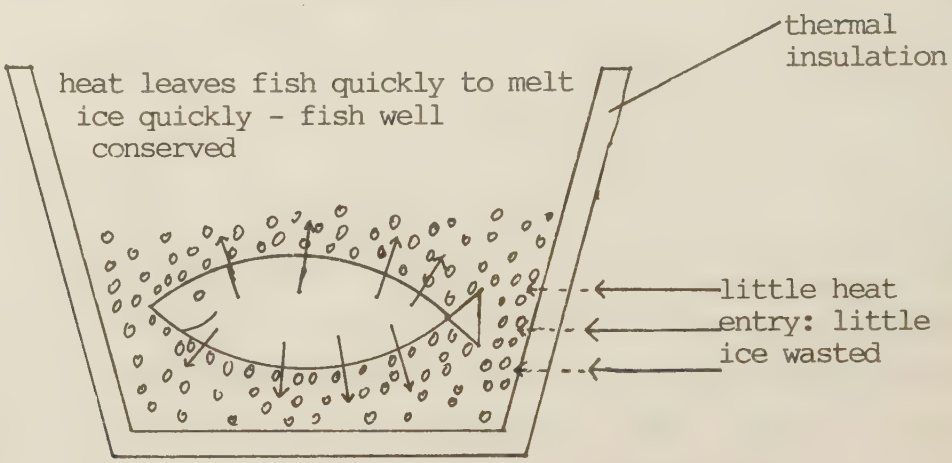
4.1.1 Types of mechanism

Heat can be transferred in three ways:

- Radiation, in which energy is transmitted directly as light, as infrared radiation, or other types of radiation.
- Convection, in which air or liquid is warmed and rises because lighter and thus circulates the heat as it moves.
- Conduction, in which heat passes through a solid, liquid or gas, from molecule to molecule.

In practice the entry of heat into fish containers is through a mixture of all three mechanisms, but in particular of conduction. The three mechanisms will now be considered in more detail to identify ways in which their effects can be reduced.

GOOD ICING - FINE PARTICLES OF ICE, THERMAL INSULATION USED



POOR ICING - LARGE PARTICLES OF ICE, NO THERMAL INSULATION

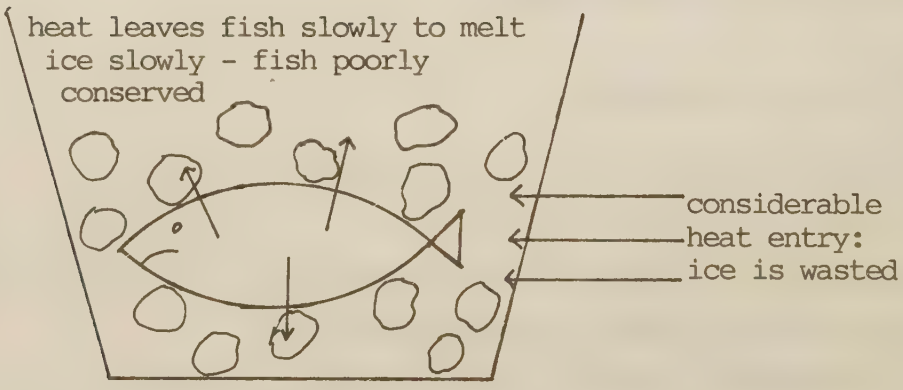


Figure 5 Good and poor icing of fish

4.1.2 Thermal radiation

We are all familiar with the heat and light radiated by the sun. This radiation passes through space and air as electro-magnetic waves. The precise physical details are outside the scope of this document but the most important aspect is that the radiation can be absorbed when it falls on a surface. As the energy is absorbed the surface will warm up. From our own experience we know that objects left out in the sun become hot.

There are two ways in which heating by radiation can be reduced. Firstly the container can be shielded from the sun's rays by putting it in the shade. Secondly the nature of the surface exposed to the sun affects the amount of energy which is absorbed and hence the rate of heating. Light coloured or shiny surfaces reflect more of the radiation than dark or black surfaces and hence will be heated less quickly. Therefore simple measures such as shading the container and painting the outside white will have a significant effect in reducing the rate at which it will be heated by the sun's radiation.

4.1.3 Heat transfer by convection

When solids, liquids or gases are heated they expand. This also means that they become less dense or in other words lighter for a given volume of the material. Liquids and gases are free to move, and so as they warm and become lighter they also rise. Conversely colder material will sink. This starts currents called natural convection currents which carry heated liquids and gases away from the source of heat, thus transferring the heat.

Heat can also be transferred by forced convection in which a fan is used to move air over an object. The air may be cold as in certain types of freezer or hot as in some types of heating. In both types of convection, heat is transferred by the movement or circulation of gas or liquid. Heat transfer by convection cannot take place in solids where movement of this type is impossible. It will also be greatly reduced if gases or liquids can be prevented from moving very far. This is an important principle in the operation of thermal insulators as discussed in Section 4.4. The use of close fitting lids will prevent hot air entering containers, a potentially important mechanism of heat entry.

4.1.4 Thermal conduction

Heat can travel through any material, be it a solid, liquid or a gas. It can also pass between any matter in physical contact. There are three factors which affect the rate at which heat is conducted through any material such as the walls of a fish container.

- The temperature difference. As heat travels from a hot object to a cold one, the rate at which heat will travel through a given material is directly related to the difference in temperature.

- The area through which the heat can travel. Just as water can flow more quickly through a wide pipe than a narrow one, heat can flow through a big area faster than through a small area.

- The ease with which heat passes through the materials used to make the container.

Thermal conductivity is a measure of the ability of a material to conduct heat.

It can be quantified numerically and is defined as the quantity of energy (in Joules) which can pass through one metre thickness of material per second when there is a temperature difference of 1°C (units of thermal conductivity are W/m deg C in the SI system of units where 1W = 1 Joule per second). Different materials have particular thermal conductivities; some examples of these values are given in Table 2. Thermal insulators have low thermal conductivities as they are poor conductors of heat. It must be noted that in general gases such as air are very poor heat conductors (i.e. good insulators) while metals are good conductors. The presence of moisture in some materials increases their thermal conductivity as although water is a moderately poor conductor of heat, it can also transfer heat by convection. Thus while dry wood is a moderate insulator, damp wood is a rather poor one.

4.2 Heat gain by fish containers

Fish containers can gain heat from:

- the sun's radiation directly warming the exposed outside surfaces
- air circulation and entry into the container
- heat conducted through the walls of the container

TABLE 1

Weight of ice needed to chill 10 kg fish to 0°C from various ambient temperatures

Starting temperature of fish (°C)	Weight of ice needed (kg)
30°	3.4
25°	2.8
20°	2.3
15°	1.7
10°	1.2
5°	0.6

(Source : Brox 1984)

TABLE 2

Thermal conductivity values of different materials at 20-25°C*

Material	Density kg/m^3	Thermal Conductivity W/m °C	Source
Wood and wood products			
Soft wood	350-740	0.11-0.16	1
Hard wood	370-1,100	0.11-0.255	1
Plywood	530	0.14	2
Balsa wood	113	0.046	4
Sawdust, loose	145	0.08	2
Wood fibre insulation board	300	0.057	2
Woodwool/cement slab	400-430	0.072-0.076	1
Cardboard, corrugated and plain sheets, bonded	105	0.047	2
Cardboard, plain sheet, waxed	710	0.12	2
Very moist wood, cardboard etc	-	0.6059	4
Cork			
Cork, granulated loose, dry	115	0.052	2
Cork, granulated	86	0.048	2
Cork, board	145	0.042	2
Cork slab	130	0.040	2
Cork board, bitumen bonded	240	0.055	2
Rubber			
Rubber, cellular slab	80	0.04	2
Ebonite, expanded at 0°C	64	0.03	2

TABLE 2 (cont'd)

Thermal conductivity values of different materials at 20-25°C*

Material	Density kg/m^3	Thermal Conductivity W/m °C	Source
Glass			
Glass fibre, lightweight mat or quilt	25	0.04	2
Glass 'wool'	52	0.038	1
Glass, cellular slab	175	0.063	2
Glass fibre, resin bonded	64-144	0.036	1
Plastic materials			
Polystyrene, expanded	15	0.037	2
Polystyrene, expanded beads	16	0.029	1
Polyurethane, foam	30	0.026	2
Polyurethane, expanded board (rigid)	30	0.02-0.025	2
Foamed in place ployurethane	24-40	0.023-0.026	1
Foamed in place urea formaldehyde	11-26	0.032-0.04	1
Polyethylene, low density (LDPE)	920	0.35	2
Polyethylene, high density (HDPE)	960	.5	2
Expanded Ebonite	64	0.0289(at 10°C)	4
Mineral products			
Mineral fibre, rock, slag or glass, loose fill	9.6-32	0.057	1
Mineral wool, felted slab or mat	180	0.042	2
Mineral fibreboard, resin bonded	240	0.042	1
Metals			
Aluminium alloy	2,740	221	1
Mild steel	7,800	45.3	1
Other natural products and insulating blankets (not compressed)			
Eel grass between strong paper	73.6	0.036	1
Eel grass in burlap	215	0.049	2
Kapok between burlap or paper	16	0.035	1
Jute fibre	107	0.036	1
Cane fibre insulation board	216	0.048	1
Polyethylene sheet+2 layers gunny (jute) fabric + polyethylene sheet	500	0.054	3
Polyethylene sheet + 4 layers gunny (jute) fabric + polyethylene sheet	580	0.046	3

Sources

1. American Society of Heating and Refrigeration Engineers (1981)
2. Institution of Heating and Ventilation Engineers (1971)
3. Venkataraman et al (1976)
4. Diamant (1986)

NOTES: *unless otherwise stated
The thermal conductivity of wood depends on its moisture content, data quoted are for normal dry materials unless otherwise stated.

These mechanisms of heat entry are illustrated in Figure 6. Heat gain can be reduced by controlling the outside environment of the container where this is possible, by good container design and by correct use of the container.

4.3. Ways of reducing the rate of heat entry into a container

4.3.1 Control of outside environment

The rate of heat entry will be minimised if the external environment is cool, hence the use of chill stores at temperatures of about 4°C for keeping iced fish (this temperature is used to allow some residual melting of ice). In fact in industrialised countries it is usual to use boxes with poor insulating properties inside a chill store or large chilled and/or insulated container. However, these relatively expensive large scale facilities are rarely available in developing countries, particularly in small scale fisheries where infrastructure such as an electricity supply may be absent. Indeed high construction and running costs make this approach inappropriate in many cases. In small tropical fisheries environmental control in this context is reduced to preventing excessive heat gain by avoiding direct sunlight or other heat sources such as fishing boat engines.

4.3.2 Design requirements for a well insulated container

The design should minimise the absorption of heat radiation by having a light coloured or reflective outer surface. Convection currents should be minimised by having a well fitting lid which stops the warm air outside the container from entering.

The entry of heat by conduction can be controlled by minimising the surface area of the container through which the heat can travel and by having well insulated walls to the container. In practice the dimensions of the container are most likely to be determined by practical convenience and tradition rather than any consideration of its thermal properties. The use of thermally insulated walls, lid and bottom is therefore a major design requirement.

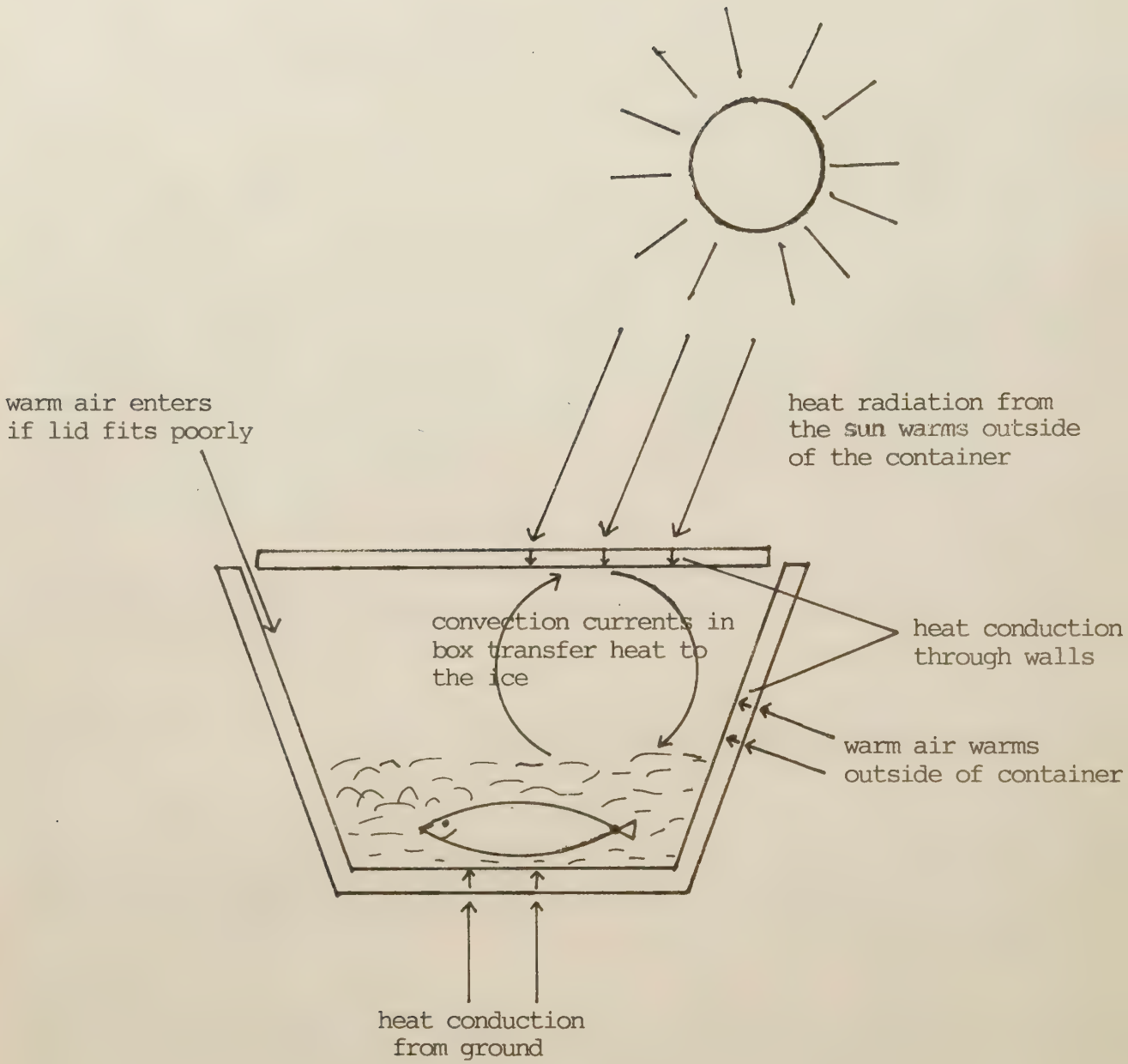


Figure 6 The entry of heat into a fish container

4.4. Thermal insulation

4.4.1 How thermal insulators slow heat transfer

It has been noted that solid materials, especially metals, are good thermal conductors while gases are good insulators. The less solid or dense the material, in general, the better its insulating properties; in fact a vacuum is a perfect insulator against thermal conduction and convection. It is therefore not surprising that lightweight materials such as plastics conduct heat less quickly than metals. However, it is materials which trap air or other gases within their structure which have the best insulating properties. Ideally the material should contain large numbers of very small bubbles. This is to reduce heat transfer by convection within the gas. The heat would then pass mainly by conduction through the small surface area of solid matter which separates the gas bubbles. If the solid matter itself is also a poor conductor, which plastics are, the result is a material with very good insulating properties. This principle is illustrated in Figure 7.

4.4.2 Types of insulating materials suitable for fish containers

Materials which trap air, such as fibres, have good insulating properties. There are various types of fibres which could be used from vegetable fibres to glass fibre. All fibres lose their insulating properties when moist and so must be well protected from the entry of water and water vapour.

Natural fibres - cotton, horsehair, wool etc have quite low thermal conductivities when new but will compact down and absorb water, and unless protected against compression will become poor insulators. These materials are also subject to attack by rodents and insects.

Fibre Glass - fibre glass matting has a low thermal conductivity but it is permeable to moisture. It also has no structural strength or compression resistance and tends to settle after installation if not properly installed. It is, however, fire resistant.

Other materials also have the ability to trap air making them reasonably good insulators. Natural products such as dry seaweed, straw, hay, feathers, charcoal, wood shavings, etc. all have relatively low thermal conductivities. Unfortunately this is only when they are dry and in a loose state with plenty of air pockets trapped in their structure. As soon as these products become

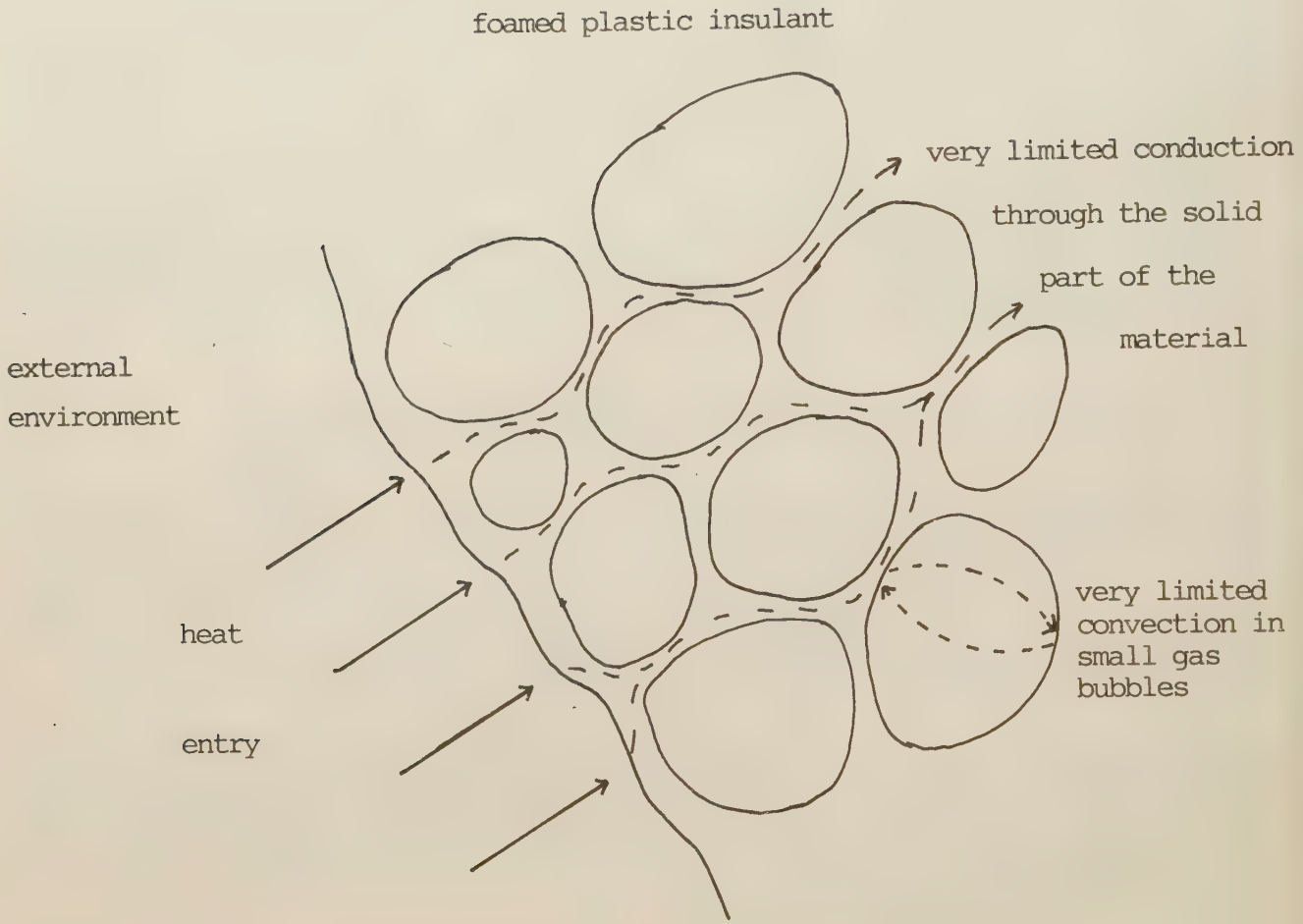


Figure 7 Many high performance thermal insulating materials (e.g., foamed plastics) are effect ve as they have large numbers of small gas bubbles trapped within their structure

damp, compressed or compacted their insulating properties are very much reduced. Granular materials such as sawdust are better than no insulation at all, but tend to be heavy and settle after installation and so become less effective. They are also not resistant to the passage of water vapour. Insulating material such as foamed plastics are available as granules but retain the general disadvantages of this type of material.

Without doubt the best insulating materials are those which have gas bubbles trapped within their structure. There are two classes of such material; plant products, notably cork, a highly effective naturally occurring insulator, and foamed plastics, developed by the chemical industry specifically for thermal insulation.

Cork - Cork used to be one of the most widely utilised insulating materials and it is still used to some extent today. It is used as slabs or in the granular form. It has good thermal insulation characteristics but if badly produced it is not resistant to water vapour. It is fairly resistant to compression and is difficult to burn. However, because of the scarcity of cork producing trees, its price today is relatively high and this is the main reason why it is not commonly used.

Foamed plastics - in recent years a large range of new insulating materials have been developed by the plastics industry. They all act by trapping small bubbles of gas within their structure and their thermal conductivities are similar regardless of the nature of the solid medium used. The major difference in thermal properties depends on whether the bubbles are interconnecting or not, non-interconnecting bubbles giving better insulating properties. There are however considerable differences in their other characteristics:

- price
- strength
- elasticity
- durability
- ease of application (e.g. as sheets, moulded containers, spray on foams, etc.)
- ability to repel water

More details of the various materials can be found in Diamant (1986). In spite of the range of possibilities only two materials have become widely popular in fisheries, expanded polystyrene and polyurethane foam. For cold stores expanded ebonite is used in some cases but is considerably less popular.

4.4.3 Expanded polystyrene

Styrene is an organic chemical which is made from oil. It can be polymerised to form a plastic called polystyrene. To produce a foam this is expanded. Two forms of expanded polystyrene are made, both of which have proved to be highly popular.

- Styrofoam

- Coalesced bead polystyrene.

Styrofoam - this is a trade name of the Dow Chemical Company. It is made by dissolving polystyrene in a solvent, adding a gas under pressure, and then extruding the mixture to give a foam with non-interconnecting pores. Styrofoam is more homogeneous and generally stronger than other expanded polystyrenes. Various grades are available.

Coalesced bead polystyrene - the raw material is small beads which can be between 0.2 and 0.6mm in diameter depending on manufacturer and specification. The beads contain an expanding agent (such as butane or pentane) which vapourises on heating. The material is supplied in sealed drums. The material can be used to make high, intermediate or low density products and will need pre-expanding for some uses. The granules are heated to expand them; the volume of the raw granules increasing by some 50 times at this stage. The prefoamed beads are stored in ventilated silos to allow air to penetrate the structure before heating again (to fuse the granules together) and moulding. The mould is then allowed to cool to give the solid expanded polystyrene product. This may be cut to size as required.

The strength and compression resistance of expanded polystyrene are dependent on the final density of the product. The bulk density of the product usually lies in the range 10-30kg/m^3 depending on the precise process used. Moulded containers usually have a higher density than sheets. The material absorbs very little water but breaks down slowly when exposed to sunlight. It is highly susceptible to solvents and fire, although fire-retardant grades are

available. Polystyrene reacts with the solvents used with the resins employed with fibre glass and so cannot be easily used in conjunction with fibre glass reinforced plastic (FRP). Its relatively low cost makes it a popular insulating material. A standard grade of coalesced bead expanded polystyrene costs about £40 /m^3 (US $ 72/m^3) ex-works in the UK (as at June 1988) for the bulk purchase of blocks. Exact prices would depend on the precise specification of the polystyrene, size of block or sheeting, quantity ordered, delivery charges etc.

4.4.4. Polyurethane foams

Polyurethane foam has a high proportion of non-connected closed cells filled with fluorohydrocarbon gases. As these gases have a much lower thermal conductivity than air, the foam has very good insulating properties. This advantage does, however, decrease with age as the gas slowly diffuses from the foam and is replaced by air. It is made by reacting a chemical called isocyanate with a resin. It is mixed with a blowing agent, which evaporates to give the gas to make the plastic foam. To make the foam the liquid ingredients must be metered accurately, mixed and dispensed. The mixture then expands rapidly, to 30 - 35 times its original volume in a minute, and then solidifies.

It can be used in several different ways.

- In open moulds, the solidified foam then being cut to the required size.

- To laminate boards, metal sheets etc, as polyurethane sticks very firmly to most solids as it is foamed.

- By injecting into a cavity.

- By spraying directly onto a solid surface.

There are many different grades of polyurethane formulated for different uses. Some are particularly fire resistant, others particularly strong, etc. Densities vary considerably, e.g., 30-40 kg/m^3 for the rigid foam "Isofoam", 105 kg/m^3 for "Bluebord CRF A65" used as a structural core in boats, etc. Manufacturers can be consulted for particular needs. The material is not particularly reactive, unlike polystyrene, but is more likely to absorb water. Although relatively expensive it is very widely used in cold, chill stores and elsewhere. Table 3 gives the ex works UK prices of Bluebord CRF A65 as an illustration, but price varies on specification, quantities ordered, etc.

4.4.5 Expanded Ebonite

Expanded Ebonite is made from rubber which contains 30% or more sulphur. It is expanded by nitrogen bubbles which are produced in the material during its manufacture. It has good insulating properties and most significantly is strong and very resistant to the entry of moisture. It is usually used as panels which can be glued to existing walls and is particularly popular in cold stores due to its durability. It is not as versatile or as widely used as expanded polystyrene and polyurethane foams.

4.5 Assessment of the thermal properties of a container

For estimating how much heat enters a container it is necessary either to measure it experimentally or to calculate it from theoretical considerations, the latter assumes that sufficient information on the thermal properties of the container is known. The calculation can be performed as shown in Appendix 2 to obtain the specific ice melting rate (K^1) for a particular type of container. Otherwise, K^1 can be estimated by putting ice into a container and measuring the rate at which it melts. If the melt water drains away this can be done by measuring the volume or weight of the melt water, or the loss in weight of the box as the melt water leaves. If the melt water does not drain away the time taken for a known weight of ice to completely melt should be determined. More details of the treatment of the data is given in Appendix 3.

Actual ice melting rates will also depend on environmental conditions such as ambient temperatures so that trials can best be conducted in a comparative way against a standard such as a commercially available container.

4.6. Effective use of insulated containers

In the previous sections, we have described how the environment and container design affect the rate of heat entry and hence ice usage. Additionally the precise way in which the containers are used will also have an influence. As a basic level it is clearly not effective to have a well designed container with a close fitting air tight lid if during the operation the lid is left open for lengthy periods. The container will be most effective when filled so that when the lid is opened there is only a small volume which can be filled by incoming warm air. Also there will be less heat transfer by natural convection if there is only a small air space left above the fish and ice.

If several containers are in use at the same time they should be stacked together. This is because heat can only enter through the outside surfaces of the stack so the containers will insulate each other at least to some extent. This is an important consideration when large numbers of containers are used for the distribution or storage of a load.

Table 4 gives a check-list of the major "do's and don'ts" for designing and using insulated containers.

5. INSULATED CONTAINERS: FINANCIAL ANALYSIS

5.1 Introduction to financial analysis

Insulated containers are usually introduced because a higher income is anticipated from a reduction of ice usage and an improved quality and price and possibly an increased quantity of fish. It is nonetheless important to verify this by financial analysis.

Financial analysis seeks to assess the cash flow of a business (in this case, the fisherman or fish trader) before and after the introduction of a new practice (here, the use of insulated containers). The objective is to determine whether or not the new practice will improve his net income, and by how much. It is therefore important to consider all the factors which determine costs and income, and to note which ones change, so as to draw a true picture of the fisherman's financial situation. The analysis should be selective, focussing only on those aspects of the business that will be affected by the proposed investment.

5.2 Some factors in financial analysis

5.2.1 The life of the investment.

There are various key assumptions in any financial analysis. It is important to have some idea of the "life" of the investment, i.e how long will the box last? (Or, will it become obsolete?, will it be stolen?) And will it have any residual value at the end of that time, i.e can it be resold, and for how much? Will it require major repairs after, say, two years, and how much will they cost? The "life" of the investment determines the length of time that the financial analysis should cover, through with very long life major investments it is convenient to use a cut-off point of, say, twenty years.

TABLE 3

Prices of a rigid polyurethane foam sheeting (Unifoam Bluebord grade A65) in the UK

Thickness (mm)	List Price (£)
6	26.33
7.5	29.69
10	34.43
12.5	35.77
15	41.99
20	50.28
25	58.20
30	67.28
40	85.75
50	98.78
75	147.00
100	185.86

Prices are Ex Works, for individual sheets of size 2 m x 1 m approximately, and were correct on 1st May 1988. Prices vary depending on number of sheets ordered and grade of polyurethane. (Source: Unitex Limited)

£1 approximately equals US$ 1.8

TABLE 4

Use of insulated containers - a check list

DO

- Do use sufficient quantities of ice broken into small pieces
- Do mix the ice and fish adequately
- Do use containers with non-toxic, non-tainting, easy to clean internal linings
- Do use a container with sufficiently good insulating properties
- Do use containers with well-fitting lids
- Do try to keep the container full when in use
- Do keep the container in the shade if possible and paint the outside white
- If chilled fish is to be packed with small quantities of ice (e.g., for air freight) do ensure that the fish is chilled through to 0° C before packing
- Do, if possible, use a container which allows melt water to drain away
- Do, if possible, stack containers together when more that 1 is in use

DON'T

- Don't put the containers near hot engines or other heat sources
- Don't leave the lid open unnecessarily when loading and unloading the container
- Don't use lead based paints, lead solders or other toxic materials in the interior of the container
- Don't use fish containers to store other items

5.2.2 The accounting period.

We need to determine an appropriate "accounting period". In project analysis this is generally a year, but small businesses may find a week or a month more suited to their planning or budgeting needs. Generally, the accounting period should cover the entire trading cycle (i.e purchase of inputs, sale of output) at least once. A shorter accounting period is probably more appropriate for artisanal fishermen, who have limited savings, and for whom the short-run cash balance is likely to be important. If there are likely to be seasonal fluctuations in income, it is important that the analysis is taken through sufficient accounting periods to illustrate this.

By convention, the investment item usually appears as a cost in "Year 0" with income appearing only in subsequent accounting periods. (Note that the investment is not depreciated over time, as is necessary in some accounting procedures; the item is shown, at full cost,in the year in which it occurs; any subsequent repairs and residual value are treated in the same way).

5.2.3 The discount rate.

A table is constructed to show the change in net income resulting from the investment. Since this represents a payment stream occurring over time,these payments need to be discounted to reflect the greater value attached to payments received in the near future. (If asked to choose between being given £1 now and £1 in a year's time, we would prefer to be given the money now; we could invest it for one year and have more than £1 in a year's time). The discount rate should be equivalent to the return that the businessman would otherwise expect on his capital, for instance, by investing in alternative ventures, or by putting the money in the bank (which may be the only realistic alternative for small-scale fishermen).

5.2.4 Inflation.

The analysis is usually undertaken using prices prevailing at the time of the investment (e.g constant 1988 prices). Inflation is ignored on the grounds that a general increase in prices will effect cost and revenue items equally, and that there will therefore be no real change in net income. Where there is good reason to expect differential inflation, i.e with some items affected more than others, it may be appropriate to consider this in the analysis.

5.2.5 "With" and "without" project scenarios.

Since we are seeking to find out how net income will change, it is important to consider the situation with and without the proposed investment. In the simple case where insulated boxes are introduced for the first time, new revenue from iced fish, less ice and insulated container costs, is compared with previous revenue from un-iced fish. In other situations it might be easier to single out specific cost and revenue items that will no longer occur, showing them respectively as "revenue" (i.e savings) and cost items (i.e income foregone).

5.3 The introduction of insulated containers to small scale fishermen in India.

It is easiest to demonstrate the principles of financial analysis by working through some examples. Table 5 illustrates a straightforward analysis of the introduction of insulated boxes to small fishermen in India (based on Clucas, in preparation). The life of the box has been taken as five years, with no residual value, and no repairs. The accounting period is one year. The investment cost is shown entirely in Year 0, as Rs12,000 (line 1). The only subsequent cost item is ice, which appears as a constant amount each year (line 2). These two items together give a stream of total costs (line 3), occurring from Year 0 through Year 5. Gross revenue is shown in line 6, derived from the sum of revenue to give net revenue (shown in line 7). In this example, it is assumed that only the quality of catch changes as a result of the introduction of insulated containers (neither ice nor containers were used previously). Increases in quantity may be achieved if longer fishing trips are undertaken as a result of the use of ice and insulated containers. It is assumed that the fisherman achieves this quality improvement immediately (although in other examples, a phased shift to higher revenues might be appropriate). Line 10 (income without box) is therefore based on the same volume of catch, but assumes that a smaller proportion is sold as "good quality" fish. Change in net income (line 11) is calculated by subtracting "net income without box" from net income with the box. Finally, line 12 shows the effect of discounting line 11 at 10%. The assumptions underlying the analysis are set out below the table.

TABLE 5

The use of insulated containers in India : Financial analysis

YEAR	0	1	2	3	4	5
COSTS						
1. Container	12,000					
2. Ice		8,000	8,000	8,000	8,000	8,000
3. Total costs	12,000	8,000	8,000	8,000	8,000	8,000
GROSS REVENUE						
4. Good quality fish		337,500	337,500	337,500	337,500	337,500
5. Poor quality fish		30,000	30,000	30,000	30,000	30,000
6. Total revenue	0	367,500	367,500	367,500	367,500	367,500
NET INCOME						
7. (Revenue less costs)	-12,000	359,500	359,500	359,500	359,500	359,500
NET INCOME WITHOUT CONTAINER						
8. Good quality fish		187,500	187,500	187,500	187,500	187,500
9. Poor quality fish		150,000	150,000	150,000	150,000	150,000
10. Total Income without container		337,500	337,500	337,500	337,500	337,500
CHANGE IN NET INCOME						
11. Net income with container less net income without container	-12,000	22,000	22,000	22,000	22,000	22,000
12. Change in net income (discounted at 10%)	-12,000	20,000	18,182	16,529	15,026	13,660

Net Present Value (10% discount rate): Rs 71,397

Pay-back period on container: less than one year

NOTES:
- Line 1: cost of container is Rs 12,000
- Line 2: cost of ice calculated on basis of ice to fish ratio of 1:1, 100 kgs fish/trip, 250 trips/year, and ice @ Rs 0.32/kg
- Line 4: 90% of catch is "good quality", valued at Rs 15/kg
- Line 5: 10% of catch is "poor quality", valued at Rs 12/kg
- Line 7: net income is the difference between gross revenue and costs (line 6 - line 3)
- Line 8: without the container only 50% of catch was good quality
- Line 9: without the container 50% of catch was poor quality
- Line 11: represents the difference income attributable to the container (line 7 - line 10)
- Line 12: represents line 11 discounted at 10%

Rs (Indian ruppees) 13.6 = US $1

5.4 Assessment of investment

5.4.1 Measures of project worth

There are then various measures of project worth that can be calculated to determine the financial desirability of one or several investments. In Table 5 "net present value" and "pay-back period" are used. Net present value is calculated by first discounting, then adding up the stream of payments "change in net income". A financially attractive venture will have a positive net present value; the most attractive venture, when choosing between alternatives, will have the largest net present value. The "pay-back period" represents the time taken for the business to recoup its investment costs, used here because of the relevance of this to small-scale operations. As with net present value, this has to be calculated using discounted values. In Table 5, the use of insulated boxes looks favourable, with a large net present value and a pay-back period of less than one year.

An alternative measure of project worth is the financial rate of return, defined as the discount rate that would set net present value equal to zero. The investor would then compare this with the rate of return he would otherwise expect on his capital. A benefit/cost ratio may also be used, where the sum of a discounted stream of benefits is divided by the sum of a discounted stream of costs, to indicate the scale of benefits relative to the amount invested.

5.4.2 Sensitivity analysis

The assumptions made in any analysis are obviously key to the results. In some cases prices may be uncertain and it is important that there is some sensitivity analysis to show the effects of alternative pricing scenarios. Tables 6 and 7 illustrate the effects of price changes that might result from the widespread adoption of ice boxes by fishermen : a smaller premium on good quality fish, and an increase in the price of ice. Where the probability of alternative prices is known, this can be used to derive an "expected value" that should be used in the calculations. Similarly, if any of the other assumptions are subject to risk or uncertainty, they can be varied in the sensitivity analysis, to show the effect on net income. Care should be taken to state clearly all the assumptions made.

TABLE 6

The use of insulated containers (assuming a smaller premium on good quality fish)

YEAR	0	1	2	3	4	5
COSTS						
1. Container	12,000					
2. Ice		8,000	8,000	8,000	8,000	8,000
3. Total costs	12,000	8,000	8,000	8,000	8,000	8,000
GROSS REVENUE						
4. Good quality fish		315,000	315,000	315,000	315,000	315,000
5. Poor quality fish		30,000	30,000	30,000	30,000	30,000
6. Total revenue	0	345,000	345,000	345,000	345,000	345,000
NET INCOME						
7. (Revenue less costs)	-12,000	337,000	337,000	337,000	337,000	337,000
NET INCOME WITHOUT CONTAINER						
8. Good quality fish		175,000	175,000	175,000	175,000	175,000
9. Poor quality fish		150,000	150,000	150,000	150,000	150,000
10. Total Income without container		325,000	325,000	325,000	325,000	325,000
CHARGES IN NET INCOME						
11. Net income with container less net income without container	-12,000	12,000	12,000	12,000	12,000	12,000
12. Change in net income (discounted at 10%)	-12,000	10,909	9,917	9,016	8,196	7,451

Net Present Value (10% discount rate): Rs 33,489
Pay-back period on container: just over one year

NOTES: As for Table 5, but with good quality fish @ Rs 14/kg

TABLE 7

The use of insulated containers (assuming a higher price for ice)

YEAR	0	1	2	3	4	5
COSTS						
1. Container	12,000					
2. Ice		12,000	12,000	12,000	12,000	12,000
3. Total costs	12,000	12,000	12,000	12,000	12,000	12,000
GROSS REVENUE						
4. Good quality fish		337,500	337,500	337,500	337,500	337,500
5. Poor quality fish		30,000	30,000	30,000	30,000	30,000
6. Total revenue	0	367,500	367,500	367,500	367,500	367,500
NET INCOME						
7. (Revenue less costs)	-12,000	355,500	355,500	355,500	355,500	355,500
NET INCOME WITHOUT CONTAINER						
8. Good quality fish		187,500	187,500	187,500	187,500	187,500
9. Poor quality fish		150,000	150,000	150,000	150,000	150,000
10. Total Income without container		337,500	337,500	337,500	337,500	337,500
CHANGE IN NET INCOME						
11. Net income with container less net income without container	-12,000	18,000	18,000	18,000	18,000	18,000
12. Change in net income (discounted at 10%)	-12,000	16,346	14,876	13,524	12,294	11,177

Net Present Value (10% discount rate): Rs 56,217
Pay-back period on container: less one year

NOTES As for Table 5, but with ice priced at Rs 0.48/kg

5.4.3 Other considerations in the financial analysis of insulated containers

The Indian example is very straightforward; other examples may entail further complications. For example, in Senegal the FAO tested two types of insulated container and compared these with the performance of the traditional box used by fishermen there (described by Coakley and Karnicki, 1984; Karnicki and Coakley, 1985). With the FAO containers, less ice was used (because it did not melt so quickly); the cost of the additional ice used with the traditional boxes would have to be included in the calculation of "net income without new box". Additionally, fishing practices changed after the introduction of the new containers - fishing voyages were longer. This means that the financial analysis would have to include the effect of fewer longer voyages in any given accounting period, yielding fish of improved quality, as compared with lower value fish obtained from more numerous but shorter voyages. There may be changes in use of fuel and labour, and in harbour fees. Besides the improved quality of fish, catches may increase, or there may be some change in the species or size composition of catch. There may be taxes on income or sales; the new investment may increase the fisherman's tax liability. All these factors need to be considered when carrying out the financial analysis.

5.4.4 Other factors which may affect adoption

Even where an investment appears to be financially attractive, there may be other reasons for not making that investment. For artisanal fishermen in developing countries, factors such as access to credit and perception of risk may be particularly important. In remote areas the supply of inputs may be erratic, and certain skills may be in short supply. Extra demands on labour may conflict with traditional roles or with other tasks. For these reasons, it is important to test any "innovations" in an environment as close to that faced by the target group as possible.

6. INSULATED CONTAINERS IN INDUSTRIALISED COUNTRIES

6.1 Use of thermal insulation in fish handling

Thermal insulation plays a vital role in chilled and frozen fish handling and is widely used in spite of the relatively cool climates of many industrialised countries. There are two approaches for keeping cooled fish insulated; either they are handled within an insulated area perhaps using containers with

little or no insulation or else the containers themselves are insulated. For example on fishing vessels it is normal to insulate the fish hold and use fish boxes (such as the returnable types described earlier) which are not insulated. In processing plants, iced fish would be held in chilled stores again in uninsulated returnable types of boxes. Polyurethane, clad with aluminium sheeting and protected by a waterproof lining of plastic, is commonly used in chill and cold store construction. Reusable insulated containers are only used in certain special situations.

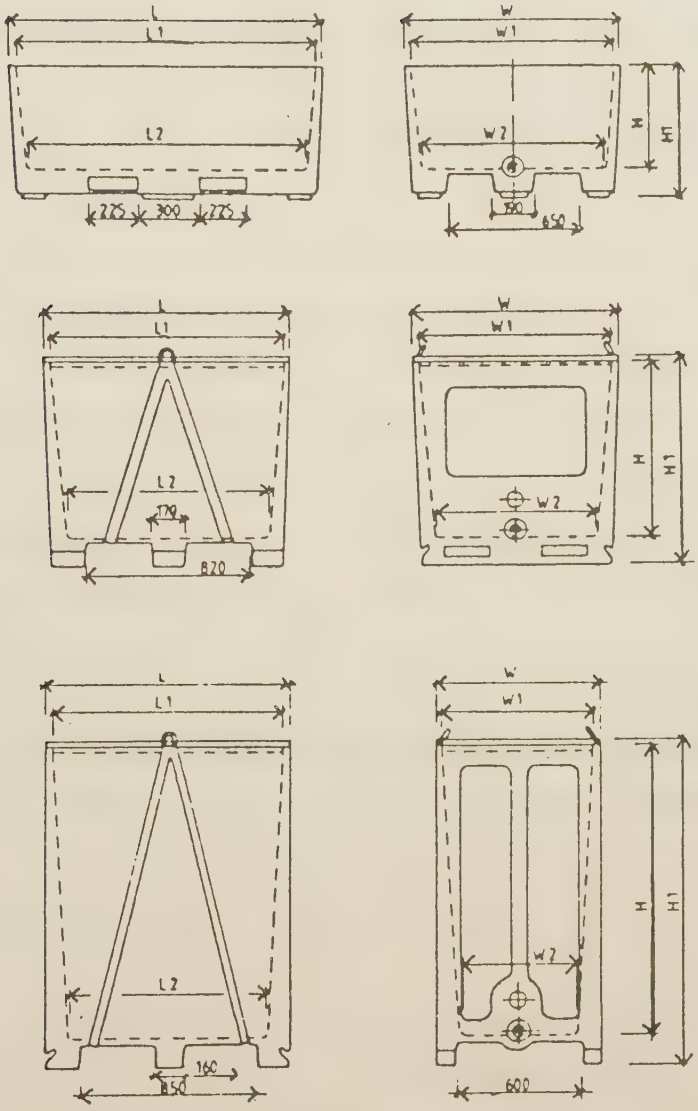
During distribution it is more usual to use non-returnable boxes which may or may not be insulated. Insulated boxes made of expanded polystyrene are certainly very popular. Also fibre board boxes with polystyrene liners are used.

6.2 Large insulated fish containers

Boxes holding up to about 25 kg of fish or fish plus ice can be satisfactorily made from fibre board or expanded polystyrene (see below), and these are normally inexpensive and non-returnable in industrialised countries. For some purposes, however, larger containers are preferred both for chilled and for frozen fish. These are of more durable construction, typically being made of either fibre glass (FRP) or polyethylene (of low or high density) and insulated with polyurethane foam 20 - 50 mm in thickness. They are very much more expensive than the simple non-returnable boxes and so are always used on a returnable basis when used for the transport of fish.

Containers of this type are almost always designed so that they can be lifted by fork-lift trucks even when they are small enough to be lifted by one or two men. This is principally a matter of ensuring that the external dimensions are chosen so that one, two or four containers fit a standard pallet accurately. All can be stacked; some can be nested when empty so that three boxes occupy the space otherwise needed for two.

Fibre glass containers are durable and can be built to any shape and volume using the same techniques which are used in fibre glass boat construction. High density polyethylene is, however, the material which is most commonly used for this type of container. They can be double walled with air as insulation between the walls, or to give a better insulated, stronger container the space can be filled with polyurethane foam. Figure 8, taken from Brox (1984), gives some examples of polyethylene containers.



type	volume approx m^3	dimensions approx in mm									weight approx kg
		L	W	H	L_1	L_2	W_1	W_2	H_1	H_2	
A	0.675	1,520	1,060	670	1,460	1,350	980	900	520	120	55
B	0.75	1,200	1,000	1,050	1,140	990	940	790	850	120	75
C	1.0	1,200	800	1,630	1,140	990	740	590	1,450	120	90

(when filled they can be stacked 3 on top of each other)

Figure 8 High density polyethylene containers
Source: Brox, 1984

Other examples of this type of container include a range made in Denmark designed to transport frozen food from cold store to retailer. These are made by rotational (centrifugal) moulding of low density polyethylene to give a seamless container, that is the inner and outer walls are made in a single sheet of plastic. Insulation is provided by injecting polyurethane foam into the cavities of both container and lid.

A range consisting of 8 larger containers between 0.17 and 1.00 m^3 (holding a maximum of 170-1000 kg) is made in Canada. All of these boxes and their lids are of double wall construction from medium density polyethylene, with polyurethane foam insulation. Lids are secured by a rubber or metal clip at each corner, and overhang the box to reduce leakage, and contamination via the lid seal. All models have a 50 mm screened drain hole, which can be easily closed if drainage is not required, and replaceable foot pads intended to prolong the life of the boxes.

Models up to 0.33 m^3 have handles, allowing man-handling, whilst all but the smallest, (0.17m^3) possess slots for fork-lift handling and a built in pallet base that allows stacking 3-4 high with or without lids. Larger boxes are strengthened by 3 steel roll bars, and the largest box features a horizontal divider to prevent crushing.

6.3 Expanded polystyrene boxes

A very wide range of expanded polystyrene fish boxes is now available in the developed world and these are commonly used for deliveries of chilled fish and frozen fish to wholesale and retail outlets. The boxes are difficult to clean and re-use, and hence are normally non-returnable. They are easily damaged or broken by rough handling. They are normally sold complete with lids, which can be designed so as to fit very closely, and can be supplied with or without drainage holes. Inset handles can be readily incorporated in the moulding. In a typical range the wall thickness varies with the box size, for example a 6 kg capacity box has a 15 mm thick wall, a 10 kg box a 19 mm wall, a 25 kg box a 25 mm wall. The extra wall thickness is principally required to give the box additional strength but does of course improve the thermal properties of the container. Table 8 gives examples of some of the products available and their prices.

More sophisticated types of polystyrene box which enable melt water to drain away from the fish to a separate compartment have been developed. The melt

water is retained within the box making this type particularly well suited for airfreight, although the more complex design makes it relatively expensive. The major disadvantages of expanded polystyrene boxes are their lack of strength limiting their size and use, and the need to supply them as moulded boxes rather than in a knock-down form; this makes them bulky and therefore expensive to transport when empty. They can also cause disposal problems at their final destinations due to their bulk.

6.4 Boxes with expanded polystyrene linings

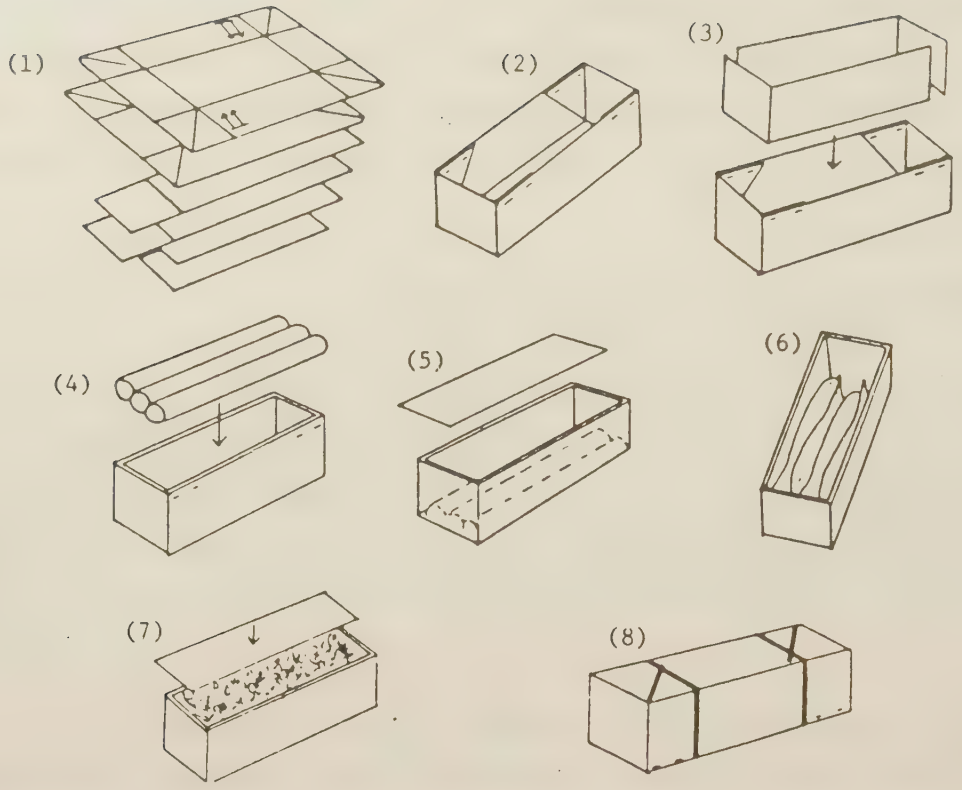
In order to benefit from the good insulating properties and relatively low production costs of expanded polystyrene, but also to have a box which when empty can be transported in a knock-down form, wooden or fibre board boxes can be insulated with polystyrene sheeting cut to the required dimensions. If lined internally with thick gauge plastic (polythene) sheeting, a water resistant insulated box is obtained. Alternatively coated fibre board can give good water resistance. This type may be cheaper than moulded polystyrene boxes in places which are distant from a moulding plant. Brox (1984) gives an example of a fibre board box insulated with polystyrene designed particularly for air-freight, the design of which is shown in Figure 9.

7 INSULATED CONTAINERS IN DEVELOPING COUNTRIES

7.1 Types of insulated containers used in developing countries

In spite of the considerable advantages of thermal insulation under tropical conditions, its use is by no means widespread. In fact the use of ice itself is limited in many areas as it is in short supply or considered too expensive. Export orientated operations, however, with their generally greater concern for maintaining quality, are increasingly using insulated containers. For example insulated containers are use to an increasing extent to hold iced shrimp on board small motorised trawlers in India; exporters of fresh fish nearly everywhere use polystyrene boxes or wooden or fibre board boxes lined with polystyrene sheeting for air-freight purposes.

The fact that the cost of icing fish will probably be higher in a tropical country than in a temperate one should not be a deterrent to the use of ice for chilling fish. In many countries chilling is the only way to make fresh fish available to people who live away from the coast and, as we have seen, the best



1. Flat packing material in store. Insignificant volume.

2. The box (and lid) is stapled together, 2 staples in each corner as near the corners as possible.

3. Two sided liner is placed in the box. The liner can be procured both with and without styrofoam. The styrofoam gives better insulation.

4. An acceptable water absorbent pad is placed on the bottom plate of the box.

5. A second bottom plate is placed on top of the absorbent pad. This to spread the pressure of the fish equally on the absorbent pad.

6. The fish is put in the box.

7. Crushed ice is thrown directly on the fish. For extra insulation a top plate of styrofoam is used.

8. A lid is finally put on and taped to the box. With approved water absorbent the box is acceptable for air transport without the tape. The box is finally sealed with tapes if requested.

Figure 9 Fibre board box for air transport

(source: Brox, 1984)

way to chill fish is to ice it. The value of the catch may, of course, be increased several fold by moving it away from the coast to inland towns where demand is high and fresh produce has a scarcity value. By adding value in this way the cost of ice and transport may be more than covered even if insulation is not used but profitability will be maximised by using insulated containers and reducing the ice bill.

In several countries although sawdust is commonly used to insulate ice blocks in ice stores, insulated containers are rarely used for iced fish. Subba Rao (1965) describes the use of sawdust, banana leaves, coconut fibre, gunny cloth, old newspapers and other simple materials as improvised insulators in the Indo-Pacific region. Clucas (personal communication) reports that in the Philippines around Manila, small expanded polystyrene boxes are used for high value fish and prawns. For distribution polystyrene insulated wooden containers are used, galvanised metal sheets being used as an internal liner. In the Amazon fishery of Bolivia similar containers are used on board the large flat bottomed pontons which act as mother ships for small fishing canoes, storing fish in ice for several days.

Lisac (1976) reviews various commercially used and experimental insulated containers in the various developing countries: polyurethane insulated fibre-glass containers were made in Zambia; plywood boxes with polystyrene insulation and a metal lining used for lobster tails in Belize; wooden containers with polystyrene insulation and aluminium lining in Indonesia.

Various experiments have also been described. Coackley and Karnicki (1984) and Clucas (1984) constructed insulated containers of wood and fibre glass, insulated with polyurethane; Wood and Grijalva (1988) describe various types of insulated and lined wooden containers; Villadsen et al (1979) conducted trials using steel barrels insulated with polystyrene.

There have been a wide variety of approaches depending on the intended use of the fish container and the materials and financial resources available. Some attempts will be made to classify the containers by their type of design and give details of construction and performance. Construction costs and suitability will vary according to local circumstances but one problem is that in many cases complete details of all relevant aspects are not available in the literature.

7.2 Use of naturally occurring fibres as thermal insulators in fish containers

While the modern plastics industry has developed many high performance insulating materials, fibrous material of vegetable origin can have reasonably good insulating properties. They have the important advantage of being widely available and inexpensive in many developing countries but in general need to be kept dry to be effective. Subba Rao (1965) describes how green leaves such as banana leaves, coconut fibre, jute fibres and even old newspapers (presumably screwed up before use) are used to line wooden boxes, bamboo baskets and other traditional containers. Some of these containers are non-returnable, others are used repeatedly.

Lupin (1986) describes how thermal insulation was made in Tanzania from dried coconut core or dried grass sealed inside plastic (polyethylene) bags. These insulating bags were put between inner and outer palm baskets to give a low cost insulated container. Some containers constructed in this way were said to have surprisingly good insulating properties, comparable to some commercially available products. However considerable variation may be expected between containers made by these simple methods. No details are available on the commercial use of this type of container although it could well be suitable for small scale fish distribution.

Andriambololonamalalanoro et al (1986) described the construction of a container with crushed peanut shell as thermal insulant. After 23 hours at ambient tropical temperatures 7.3 kg of ice held in this container melted. This compared with 4.5 kg ice melting in a similar container insulated with 60 mm of polystyrene (no data is given for uninsulated containers). If protected from moisture by, for example, putting the peanut shell in sealed plastic bags, this would be an inexpensive material with moderate insulating properties.

At the most simple level the thermal characteristics of wooden containers can be improved simply by keeping the wood dry. Plastic liners or non-toxic water resistant paint can be used. Plastic liners can also be used in bamboo baskets to cut down the entry of heat by convection currents. These approaches will additionally give surfaces which are relatively easy to clean. Balsa wood has good insulation properties and if coated with fibre glass gives strong lightweight containers. One fish trader recently started using boxes of this type on fishing launches in Ecuador. The relatively high cost of these containers should be offset by their durability, although details of their per-

formance are not available. The major disadvantage of this system is that balsa wood will rapidly absorb water if the fibre glass is damaged.

Perigreen and Govindan (1969) investigated the use of bamboo baskets lined with various materials for the distribution of iced fish in India. The more important findings are given in Table 9. Although the polystyrene was by far the most effective lining, these more simple inexpensive linings nevertheless significantly extended the period for which the fish remained cool.

7.3 Suitability of insulated containers from industrialised countries

As insulated containers are produced and used in industrialised countries, it would be a logical first step to consider the extent to which these types are used or are suitable for small scale fisheries in developing countries. The greatest restriction is their high cost relative to the containers currently in commercial use. The same restraint has greatly restricted the use of modern fish boxes as was noted in Section 2.

Insulated returnable containers are only used in special situations in industralised countries and it is probably unrealistic to expect these designs to have a wide application in developing countries. Nevertheless they may be suitable for high value products such as shrimp. Expanded polystyrene containers, which are commonly used as non-returnable fish boxes in industrialised countries, are considerably cheaper and are used to some extent in developing countries as non-returnable boxes specifically for the export of high value products (eg by air freight). They are also used as re-usable containers. Clucas (personal communication) has described how expanded polystyrene boxes are used extensively on small boats and markets in the Manila area of the Philippines. Significantly they are used mainly for high value fish and prawns.

Expanded polystyrene boxes have two technical disadvantages for use as re-usable containers; they are fragile, and difficult to clean. Venkataraman et al (1976) found that 25 mm thick moulded polystyrene boxes could not withstand a single trip by train from Gujarat to Bombay or Delhi and suggested that this type of box would have to be completely sheathed in a strong material to enable it to withstand rough treatment. Clucas (personal communication) indicated that some fish traders use external wooden frames or metal strapping to support and protect the boxes, while smooth plastic liners are used both to protect the

TABLE 8

Expanded polystyrene fish boxes available in the UK

Maximum weight contents(kg)	External dimensions (mm)	Price (£) (Ex works)
3	400 x 300 x 88	0.371
6	400 x 300 x 130	0.45
8 (no lid)	480 x 360 x 146	0.3657
8	505 x 363 x 146	0.5618
10	505 x 363 x 172	0.648
11	590 x 360 x 160	0.72
12	590 x 360 x 180	0.7525
15	600 x 400 x 229	1.2826
17	600 x 400 x 259	1.34
20	710 x 420 x 198	1.34
22	600 x 400 x 312	1.43
25	710 x 420 x 260	1.44

The boxes can be provided with or without drainage holes.

All are provided with lids unless otherwise stated and with hand holes in ends for ease of handling.

Prices quoted are ex works, excluding tax and subject to minimum orders. They were applicable in November 1988.

Source: G T Enterprises (Littlehampton) Ltd

£1 = US$ 1.8

TABLE 9

Storage life of iced fish in different containers

Fish: ice 1:1 (Alternate Layers) Ambient Temperatures 26 to 32°C

	Container	Maximum storage life in hours
1.	Bamboo basket (plain)	11-12
2.	Bamboo basket lined with kraft paper	19-21
3.	Bamboo basket lined with gunny and polythene	21-22 1/2
4.	Bamboo basket lined with palmirah leaf mat	20-22
5.	Bamboo basket lined with banana leaves	18-20
6.	Bamboo basket with sawdust on top	24-27
7.	Bamboo basket line with 25 mm expanded polystyrene	60

Source: Perigreen and Govindan, 1969

polystyrene internally and to give a washable surface. This approach certainly seems effective where there is an inexpensive supply of boxes of this type, which will almost certainly mean in areas where factories making the boxes are located, as their bulk makes them expensive to transport. Few details of the performance and durability of the containers used in this way are given in the literature.

Various experimental trials have been conducted using returnable insulated containers. Fischer and Larsen (1981) describe how insulated containers holding chilled sea water (ice plus an equal amount of sea water) was successfully used to chill fish on board a small fishing boat in Denmark. The system was very successful in rapidly chilling and maintaining the quality of the catch, while discharging the container was said to be easy as it could be taken out loaded by a dock side crane. This system was considered to be an indication of the potential for this container in small scale fisheries in developing countries.

In contrast Teutscher (1986) found insulated containers of 0.07m³ (70 lit) and 0.2 m³ (200 lit) capacity unsuitable for longer storage of fish in chilled sea water due to the difficulty in mixing ice with the fish when new ice is periodically added. As a result the lower layers in the containers tended to have a significantly higher temperature then the top layers. The bottom layers were also more contaminated in particular with blood and the fish spoiled faster, eventually giving an "off" flavour to the whole container. After the modification of the containers giving them drainage points the containers were technically successful in keeping iced fish, although the 70 lit containers were not suitable due to the considerable volume taken up by the insulating material. This illustrates the need to have containers which are suitable for their intended use; containers designed for mechanical handling systems may well not be suitable for the small scale fisheries while the cost of making relatively small numbers of purpose built containers by similar techniques may be prohibitive.

7.4 Fish containers insulated with expanded polystyrene

Although the insulated fish containers and boxes made in industrialised countries may have limited application in developing countries, advanced insulating materials can be incorporated into locally made containers. Other than the moulded expanded polystyrene containers described earlier, expanded polystyrene is also available in sheets. Although still a bulky material, it is considerably less bulky than an empty non-nesting container and therefore is less expensive to transport. Sheets are available in many countries in various thicknesses and in standard sizes (e.g., in Ecuador sheets were 2 m x 1 m and available in thicknesses of 10, 20, 25, 50 mm and thicker). The

sheets can be easily cut to size to insulate most types of container. A limitation is that the resins used with fibre glass react and destroy polystyrene and so this combination of materials cannot easily be used.

Villadsen (1979) describes trials conducted in Sri Lanka in which a steel barrel (formerly an oil barrel) was insulated with polystyrene for use for storing iced shrimp. Uninsulated barrels were in use for the same purpose at the time when the trials were conducted. The barrels could be used with their tops removed or else cut into halves. 38 mm thick polystyrene sheeting was cut to fit inside the bottom of the barrel. The same thickness of polystyrene was then used for the sides, 40 mm wide lengths being cut with angles of 94° and 86° so that the sides fitted together inside the barrel. The final length locked the circle of polystyrene. An inner barrel of galvanised iron was then inserted and the top sealed with a plastic compound to stop water penetrating the insulating sheath. A lid was made of marine plywood and insulated with polystyrene sheeting. The design was later modified to use 12mm thick expanded polystyrene sheeting at the sides as it was found that this thickness of material could be bent inside the curve of the barrel without breaking. Three sheets of polystyrene were used to give the required total thickness of insulation. The design is illustrated in Figure 10.

More commonly, polystyrene sheeting has been used to insulate wooden containers used on board fishing boats and for distribution. An internal lining is necessary to prevent physical damage to the polystyrene and the entry of water. Metal linings have proved popular although galvanised steel is not recommended as the zinc coating also contains lead and cadmium, both of which are highly toxic. Alternatives are, however, relatively expensive. Wood and Grijalva (1988) constructed two wooden containers insulated with polystyrene for use on-board small fibre glass fishing launches. The outer containers were of 9 mm marine plywood supported on a wooden frame. 25 mm thick polystyrene was used. One box was lined internally with 6 mm marine plywood, the other with 0.2 mm thick galvanised steel sheeting soldered using pure tin solder. The wooden lining, although relatively cheap, was heavy and proved not to be very durable. Durability trials on the other box are incomplete but perhaps a thicker guage steel could have been justified to give a slightly heavier more durable container. The design is illustrated in Figures 11 (which shows the wooden frame) and 12 (which shows a cross section). A photograph of an unlined box showing the polystyrene insulation is given in Figure 13. The production costs together with those for a polyurethane insulated fibre glass lined container are given

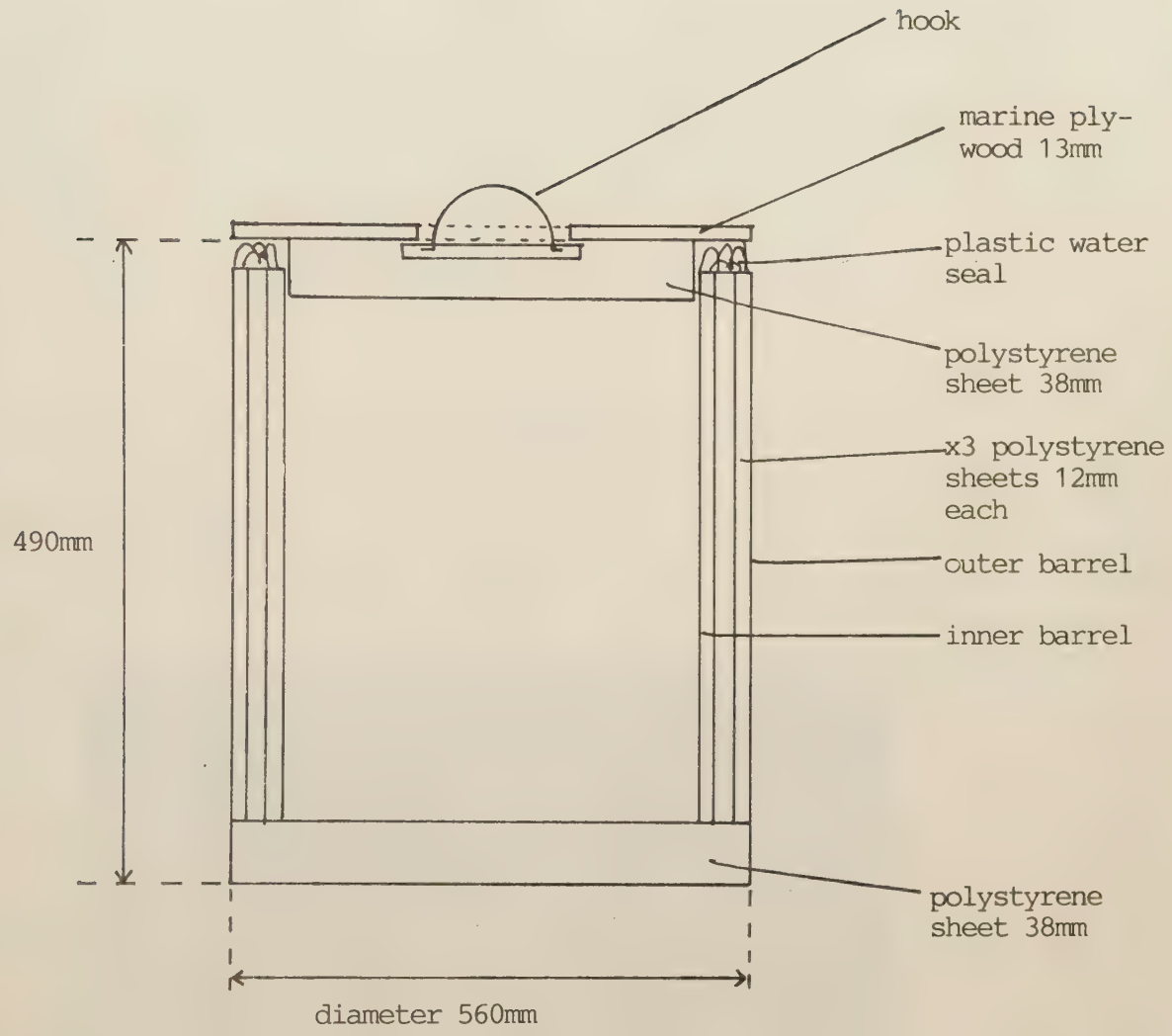


Figure 10 Insulated oil barrel

(source: Villadsen et al,1979)

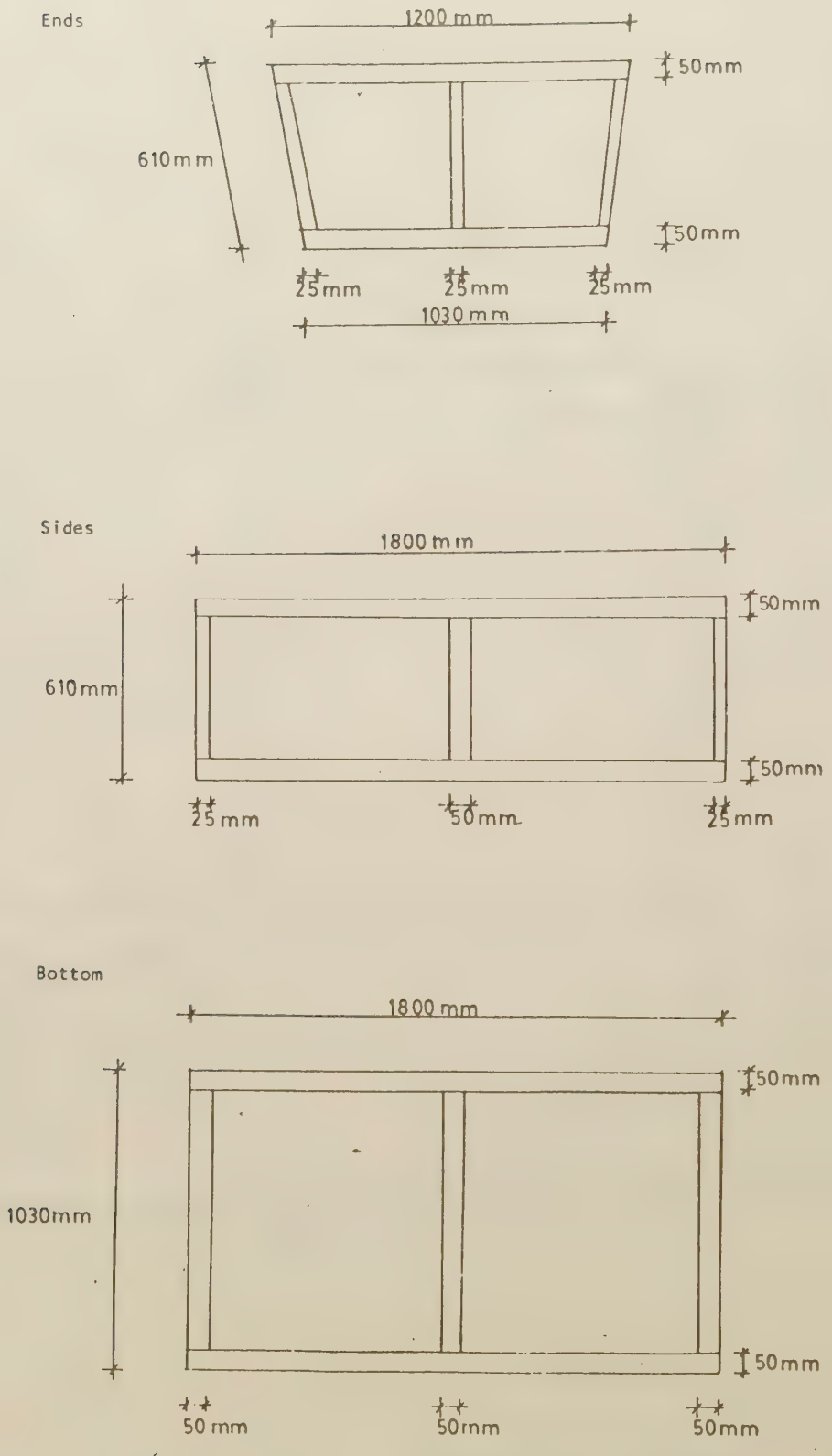


Figure 11 Wooden frame for insulated container

(source: Wood and Grijalva, 1988)

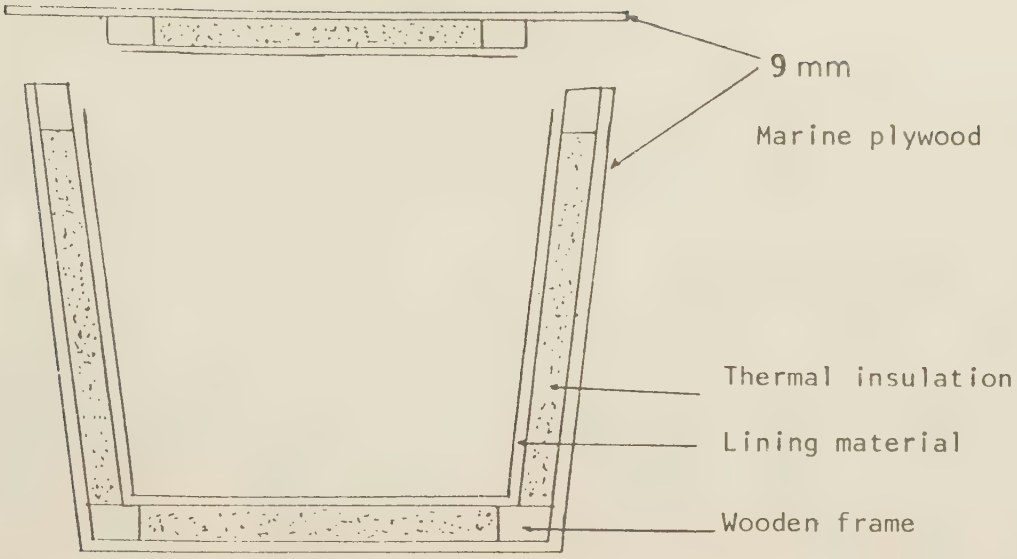


Figure 12 Cross section of a wooden insulated container
Source: Wood and Grijalva, 1988

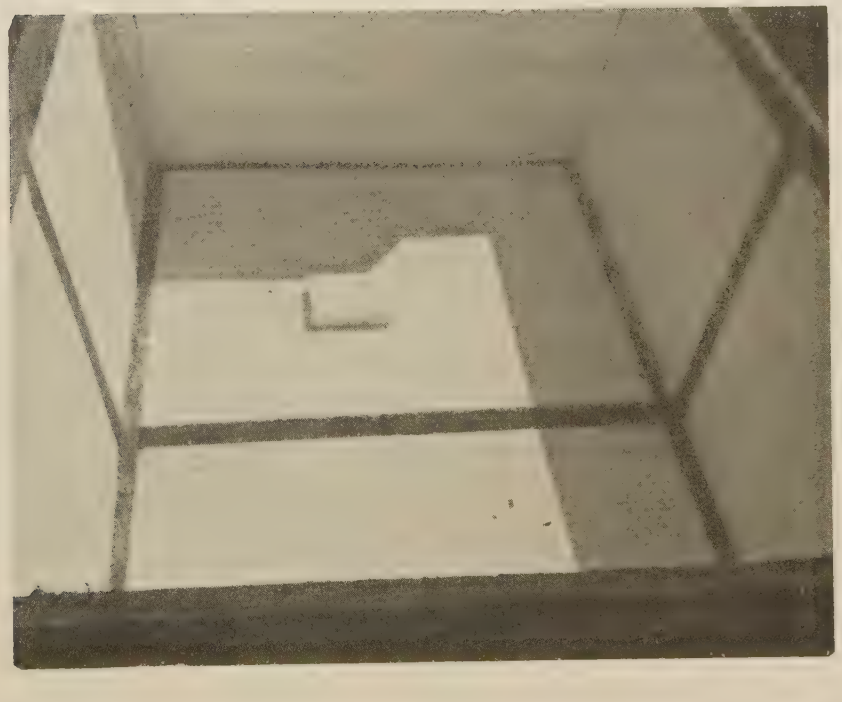


Figure 13 Wooden box insulated with expanded polystyrene before lining internally

in Table 10. Similar designs exist in Bolivia, Sudan, Senegal and probably elsewhere.

Perigreen and Govindan (1969) described how old tea chests were lined internally with 20 - 25 mm thick polystyrene sheeting for the distribution of iced fish. The polystyrene was cut to size and sealed in polythene bags to prevent contact with the melt water. Iced fish (ratio fish:ice 1:1) could be kept cool for 55 to 60 hours at ambient temperatures of 26 - 32°C whereas the uninsulated box enabled the fish to be kept cool for just 14 - 16 hours. Venkataraman et al (1976), using the same type of container as shown in Figure 14, recommended 25 mm thick polystyrene during the hot season, with fish:ice ratios of 4:3 being adequate for the 40 hour journey from Gujarat to Delhi. 15 mm thickness polystyrene was adequate for the cool season and the fish:ice ratio could even be reduced to 2:1 in particularly cool weather. The containers lasted for two to five trips.

7.5 Fish containers insulated with polyurethane foam

Fibre glass is strong and light making it a very useful material for fish containers, although it is relatively expensive. Polyurethane does not react with the resins used to make fibre glass reinforced plastic (FRP) thus is used instead of polystyrene in containers made with this material. Polyurethane is, however, generally less widely available in developing countries and is expensive. For example in Ecuador it was approximately twice the price of polystyrene sheeting (see Table 10).

Various trials have been conducted using polyurethane and fibre glass containers. Coackley and Karnicki (1984) designed and constructed a container to fit inside fishing canoes used in Senegal, West Africa. The container had 100 mm of high density polyurethane coated in fibre glass (FRP) and a wooden top as a deck, removable wooden lids and wooden skids on the base. Construction details are given by Coackley and Karnicki (1984) and are described in Appendix 4.

The performance of this container relative to galvanised steel lined wooden containers with 50 mm of polystyrene insulation is given in Table 11. In spite of its good technical performance which appeared to make it economically attractive, it did not prove to be entirely satisfactory. The improved container was fragile and damage was difficult for the fishermen to repair, it was heavy and the extra thickness of insulation took up too much space. Also the high

TABLE 10

Cost of a polystyrene insulated/galvanised steel lined container and a polyurethane insulated/fibre glass lined container constructed in Ecuador

Item	Quantity	Cost (S/-) Polystyrene/ steel	Cost (S/-) Polyurethane/ glass fibre
Outer box (same for both designs)			
9mm marine plywood (2.44m x 1.22mm sheets)	3 sheets	11,340	11,340
Wood) Nails) Paint, sealant) Labour)	as required	7,000	7,000
Sub Total		18,340	18,340
Insulation			
Polystyrene (2m x 1m, 25mm thick)	3 sheets	6,630	
Polyurethane (2.44mm x 1.22m, 25mm thick)	2½ sheets		15,750
Lining			
Galvanised steel (1.8m x 0.8m, 0.22mm thick)	8 sheets	16,000	
Paint	1½ litre	1,125	
Sealant, resin	1½ litre	2,030	
Tin solder	0.68 kg	5,740	
Grease, nails, labour	as required	3,500	
Fibre glass (980mm wide, 375 g/m grade)	15m		16,500
Resin	16 litre		20,800
Acetone	1 litre		1,625
Paint	5 litre		8,125
Catalyst	200 ml		400
Labour	as required		3,000
Sub Total		28,395	50,450
Totals		53,365	84,540

NOTES: Costs are given in Ecuadorian Sucres (S/-) as in May 1988. They should be regarded as indicative only as prices and exchange rates were very unstable at this time. The prevailing exchange rates were

US $ 1 = S/275 (official import/export rate); S/460 (free market rate).

TABLE 11

Performance of polyurethane and fibre-glass (FAO) container compared with commercial container insulated with polystyrene

	Commercial container insulated with (length 2.5m)	FAO Container, Polyurethane Insulated (length 2.5m)
Days at sea	3-4	5-6
Value of landings (Franc CFA)	100,000-150,000	1,000-250,000
Quantity of landings (kg)	800-1,200	1,000-1,500
Quantity of ice used (kg)	1,200	700
Average price of the fish (Franc CFA/kg)	100	170
Cost of container (Franc CFA)	150,000	400,000

(Source : Teutscher, 1986)

360 Franc CFA = US $1 (1 January 1984)

TABLE 12

Insulated containers constructed by Clucas (in preparation)

	BOX		
	1	2	3
Dimensions (internal)			
length (m)	1.3	1.24	1.04
width (m)	0.6	0.59	0.54
depth (m)	0.72	0.59	0.44
Capacity (m^3)	0.562	0.432	0.247
Lid	centrally opening	opening 150mm from 1 end	opening 150mm from 1 end

All boxes fitted with a longitudinal divider, closeable drainage hole and external carrying handles.

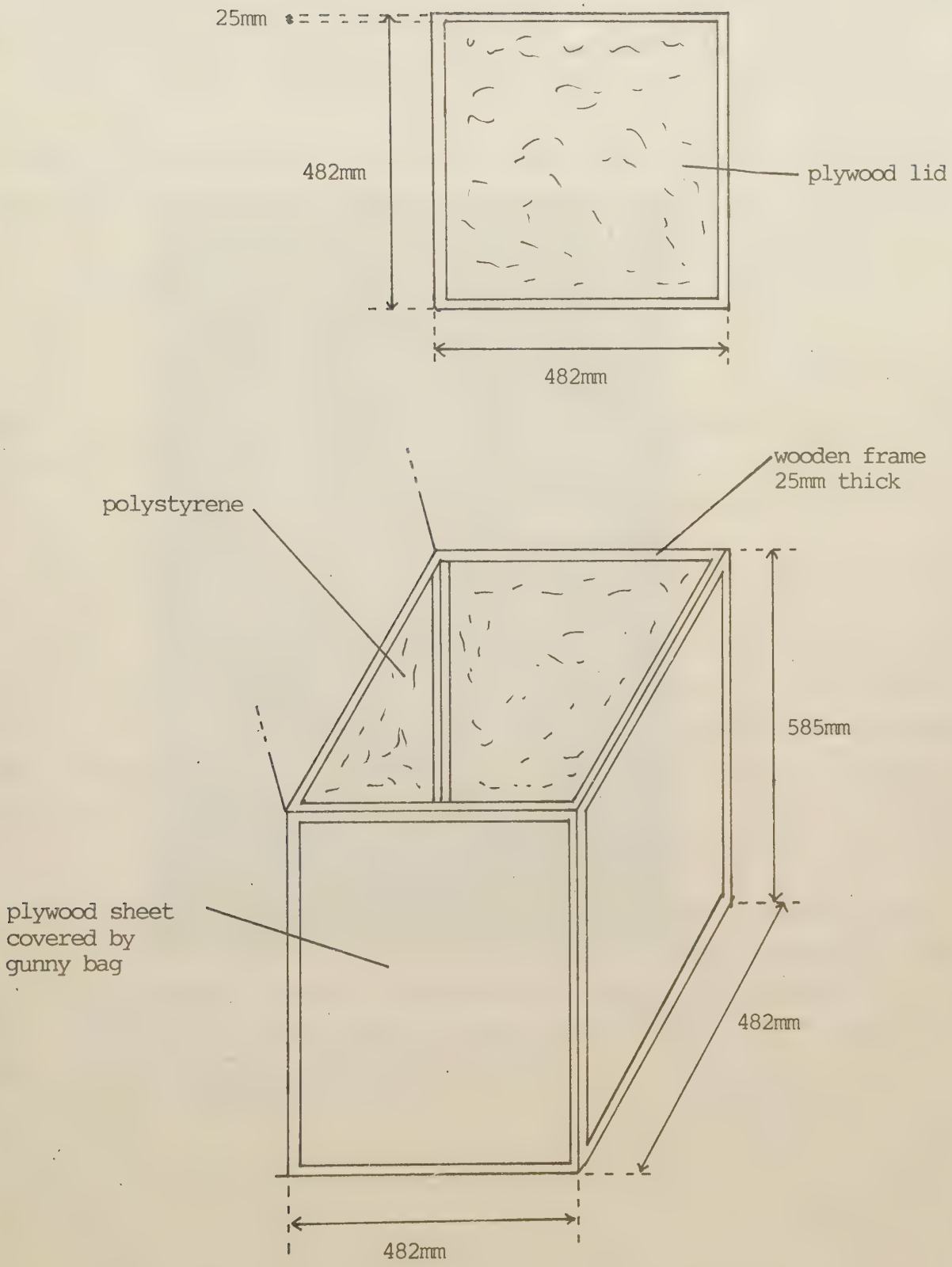


Figure 14 Insulated wooden box made from a tea chest
(source: Venkataraman et al, 1976)

initial investment was not favoured by the fishermen even though the extra cost could be covered by the savings produced after just three fishing trips. Teutscher (1986) suggested that a polystyrene-insulated, metal-lined (with non-corroding zinc or aluminium) wooden container would be more attractive to the fishermen. It was also suggested that steps should be taken to protect the wood from water such as using plastic sheeting as a vapour barrier.

Clucas (in preparation) describes the use of experimental designs of insulated fish containers in India on board fishing boats. The designs tested were:

1. Outer 9 mm marine plywood shell, insulated with 35 mm polyurethane coated with glass fibre reinforced plastic (FRP), 1.5 to 2 mm outside, 3.5 mm inside.

2 and 3 as box 1 except with 70 - 75 mm polyurethane coated with 3 - 4 mm FRP. A photograph of this design under construction is presented in Figure 15 and further details given in Table 12.

Other than problems of adjusting the box dimensions to fit better into the particular boats, the first box designed was considered to be heavy. 35 mm insulation was also considered inadequate for the particular circumstances. Both designs were expensive and Clucas (in preparation) considered that the fishermen were unlikely to buy boxes of this type. These trials are presently incomplete but preliminary analysis indicates that even these relatively costly boxes may be attractive financially. More details of a financial analysis of this project have been given in Section 5.3.

Wood and Grijalva (1988) describe the construction of a container similar to type 1 described by Clucas (in preparation) except 25 mm polyurethane was used and the FRP was used only as an internal liner, the marine plywood being painted to give some protection from water. The boxes were designed to be used on small fibre glass launches which make relatively short fishing trips. As with those of Clucas (in preparation) these trials are not as yet completed. The design is closely similar to that shown in Figures 11 and 12 (in Section 7.4); the cost of this type relative to similar containers using polystyrene as the insulator have been shown in Table 10.

Ben Naceur et al (1987) described the construction of an insulated mini-trailer for fish transport and retail. The trailer features a container made from polyester (internally and externally) insulated with 40 mm thick polyurethane

Figure 15 Fibre glass reinforced plastic (FRP) box being insulated with polyurethane foam sheeting.
Photograph courtesy of Bay of Bengal Project/K Vijaykumar

foam. It was found that it was more convenient to inject the foam between the inner and outer plastic boxes rather than use sheeting. Initial financial analysis indicated that the trailers could be attractive to street fish sellers. Again these trials are not yet completed.

7.6 Other insulated containers

Insulated containers originally used for other purposes may become available to fishermen or fish traders. One example of this is the use of old broken-down domestic refrigerators and freezers for keeping iced fish. These are bulky and heavy, but nevertheless can be used to good effect in market stalls. In Zambia their use is quite common in the markets of Lusaka. Also packing materials may be very useful as insulators and could be available relatively inexpensively in particular locations. Polystyrene is commonly used in packaging to protect fragile goods during transport. Useful oddments could be obtainable when imported equipment is unpacked. Various plastic paddings used for similar purposes could also be useful.

Simple improvements to traditional fish containers may improve their thermal performance without the use of insulating materials as such. The technique for using the Malaysian wooden boxes has been modified in recent years in a very simple way. The boxes, which hold on average some 150 kg of fish/ice mixture, are lined with a thin gauge polythene sheet. The plastic liner provides an hygienic package for the fish, reduces the rate at which the box deteriorates through wetting but, most imortantly, reduces the melting rate of the ice. This provides significant savings in costs by reducing the ice to fish ratio for a given journey. The lower ice to fish ratio not only reduces ice costs but also lowers distribution costs by enabling a greater weight of fish to be carried in a box.

The very thin layer of polythene sheet has almost no insulating properties as such; it provides a seal so that heat movement by convection through the box surfaces is stopped, and reduces conduction because the wooden box remains dry. A similar technique is reported from Indonesia where rattan baskets are lined with polythene sheet (Kamari and Sayers, 1979). Where polythene sheeting is difficult to obtain baskets may be lined with banana leaves to similar effect. The principle is illustrated in Figure 16 which is applied particularly for large fish in Indonesia, a polythene bag rather than sheet being used in this particular case.

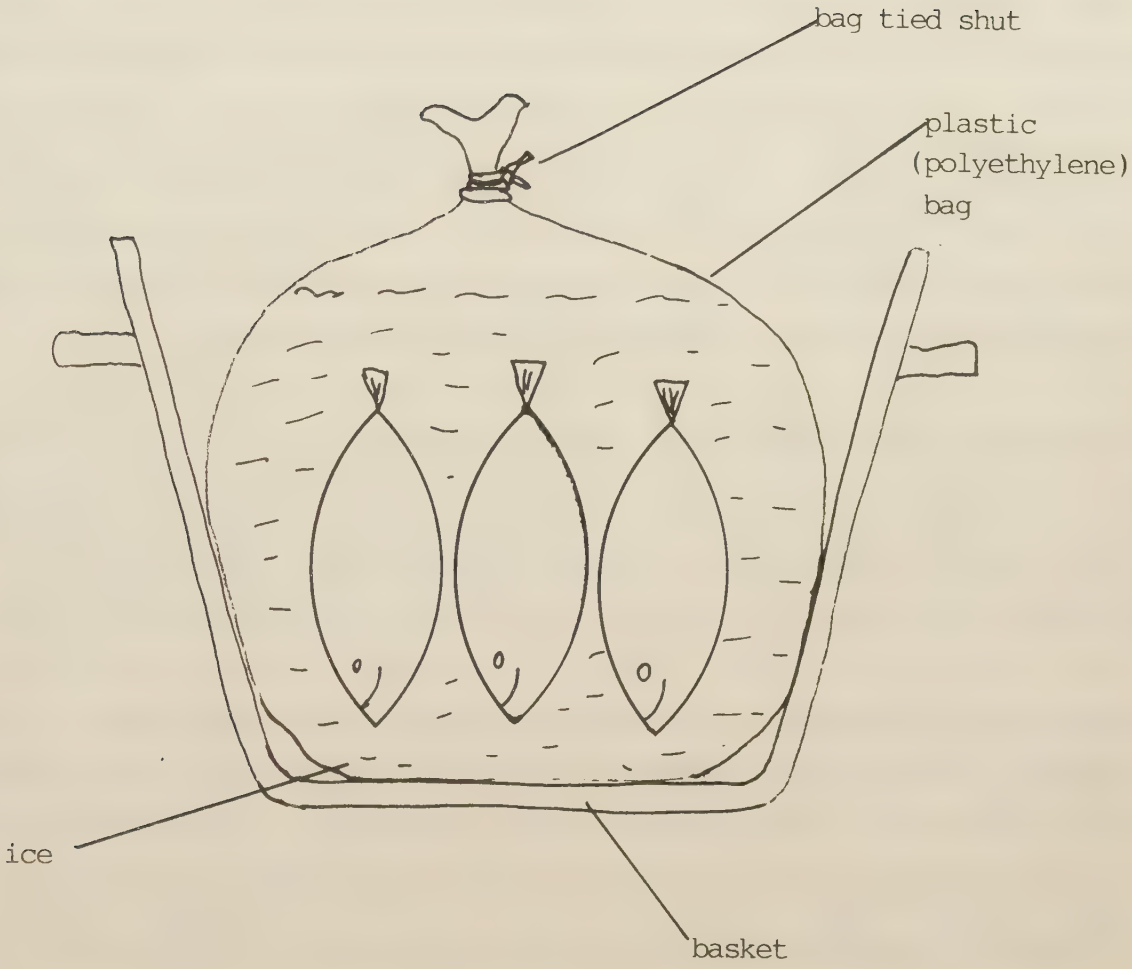


Figure 16 Improved method of carrying large fish in ice in baskets

8. DISCUSSION

8.1 Use of thermal insulation in small scale tropical fisheries

As a common approach in industrialised countries is to use a large insulated space or container within which smaller uninsulated containers or boxes are employed, it is worthwhile considering the same approach in developing countries. On fishing boats it may be easier and more cost effective to insulate a fish hold or integral container rather than construct a separate insulated container. Similarly during distribution insulated lorries or insulating covers may be more suitable than using insulated containers. Large numbers of insulated containers in a single load is an inefficient way of utilizing what may be a very limited space. For this reason Teutscher (1986) found that the use of certain designs of insulated containers reduced the transport capacity (for fish) of a lorry by 50% which was clearly unacceptable.

Nevertheless in many small scale fisheries the quantities of fish handled mean that only relatively small containers are required. Partially filled insulated spaces or containers are inefficient both thermally (as heat transfer by convection will occur) and financially (as an expensive facility is being underused). Without doubt in many situations insulated fish containers are very suitable.

In small scale fisheries it is essential that any containers used are not too expensive. Although very durable, but expensive, containers may be attractive in the longer term, the small scale fishermen or trader may not have the capital or access to credit to make the initial outlay. Less expensive, less durable containers may be preferred. Also the detailed design will vary from one place to another; one type or style of container is unlikely to be universally applicable. Therefore there may be little advantage in using factory mass produced models for small scale fisheries. The following discussion will therefore centre on the relative merits of different styles of construction for insulated containers and on factors which may influence detailed designs under particular circumstances.

8.2 Locally available vegetable fibres or foamed plastics as insulating materials.

Vegetable fibres will often be relatively cheap in developing countries compared to foamed plastics. Foamed plastics do, however, perform better as insulators so the extra expense may well be justified. The relative merits of the insulants

will depend on their respective prices and availabilities, also on the precise nature of the fishery and products produced. Nevertheless it is clear that inexpensive vegetable material could provide very suitable albeit only moderately effective thermal insulation and should receive far greater attention than has previously been the case. The limited work done on packing plastic bags with material such as dried grass has demonstrated that the approach has some potential.

8.3 Construction methods for insulated containers

Although polyurethane injected polypropylene containers or those made of FRP and polyurethane sheeting are technically good, for many fisheries in developing countries they are too expensive. This expense may be justified in some cases, particularly for the export of highly priced products, but in many situations metal or wooden containers insulated with expanded polystyrene or vegetable fibres would be preferred due to their lower cost. The major problems with this style of construction is the weight of the container, due mainly to the wood, and the internal lining material. Galvanised steel is used as a lining but is not recommended as the zinc coating contains toxic metals. Similarly zinc itself is not recommended. Non-galvanised steel can be used but corrodes. Salt water greatly accelerates the corrosion of steel so its durability would be particularly poor in marine fisheries. Non-toxic paints can give some protection and regular repainting may give an acceptable working life. Aluminium would appear to be suitable, if expensive, and should be investigated. Its potentially long service life and lightweight would be major advantages.

Cheaper, lighter, but less durable materials such as bamboo baskets may also be suitable, particularly in combination with cheap vegetable fibres to make inexpensive, possibly non-returnable, containers. Improvisation using locally available containers such as tea chests and oil drums has also been successfully used.

Fish containers should ideally have drainage points in the bottom to allow melt water to escape. If it is impractical to provide these it may be worth constructing a removable false bottom. Water would drain into the bottom compartment so that the fish does not become immersed. Also internal dividers may be useful to segregate clean ice from iced fish and to prevent excessive movement of the contents of the container.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

1. Thermal insulation is widely used in the fisheries industry in industrialised countries to save ice and energy and help maintain the quality of the products. Its use in small scale fisheries in developing countries is less widespread even though it is of great potential benefit.

2. Several types of insulated containers are used in industrialised countries, but they are of limited application to developing countries.

3. A variety of insulated containers have been and are used commercially and experimentally in developing countries. The suitability of each type depends very much on the local circumstances and generally each has its comparative advantages and disadvantages. Often a balance between technical performance and cost must be struck.

4. Although several interesting pieces of work have been described, case studies with a complete analysis of container construction, performance, durability, suitability and cost are few.

9.2 Recommendations

1. Further research and development work is required to compare the different types of insulated container in different situations.

2. Suitable containers can then be introduced in extension programmes to widen the use of thermal insulation, particularly in the small scale fisheries in developing countries.

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Baxenden Chemicals Ltd., Paragon Works, Baxenden, Nr. Accrington, Lancashire BB5 2SL, UK

Cold Fish, Falkenbergsgatan 3, 412 97 Goteborg, Sweden

Dynoplast Ltd., North Seaton Industrial Estate, Ashington, Northumberland NE63 OYB, UK

G.T. Enterprises (Littlehampton) Ltd., Lineside Industrial Estate, Littlehampton Sussex BN17 7HE, UK

Shell Chemicals UK Ltd., (Polymers Business Centre), Heronbridge House, Chester Business Park, Wrexham Road, Chester CH4 9QA, UK

Unitex Ltd., Knaresborough, Yorkshire HG5 OPP, UK

Vencel Resil Limited, Anderson Way, Belvedere, Kent DA17 6BG

Xactics Limited, PO Box 2087, St. John, New-Brunswick, Canada, E2L 3T5

APPENDIX 1

Codex Alimentarius Commission recommendations for fish boxes (as quoted and commented upon by Clucas and Whitehead, 1986)

The Recommended International Code of Practice for Fresh Fish (Codex Alimentarius Commission, 1976) gives various recommendations for design and use of fish boxes for iced fish at sea and ashore. These include:

All tubs, barrels and other containers used for handling and conveying fish should be of corrosion-resistant material and easy to clean.

In many areas wicker baskets are used for handling fish on deck. These are very difficult to clean properly, as slime, blood, scales and small pieces of offal or parts of fish body may become lodged within the framework. Containers with smooth, waterproof surfaces which are easy to clean and disinfect are recommended for handling fish on board the vessel or on shore.

All containers used for ice storing of fish should be of uniform and suitable size, easy to handle when loaded, and should be constructed of suitable corrosion-resistant material.

Such containers should be capable of accommodating the larger fish without bending and, when fully loaded, they should be easy to handle by one or two men without tilting, tipping or jerking. If wooden boxes are used, they should be of smooth construction and of durable, non-toxic and waterpoof finish. Baskets should not be used for handling fish on board the vessel or on shore, as they are difficult to clean and disinfect.

Containers should be large enough to hold adequate quantities of ice as well as the correct weight of fish. They should be strong enough to withstand fairly rough handling and be suitable for stacking when filled, without damage to fish in stacked boxes.

As the fish should always be well iced, it is necessary that the containers be large enough to hold adequate quantities of ice for the standard amount of fish being sold. It should be possible to stack containers close together to reduce the amount of heat absorbed from the surrounding atmosphere. Good drainage arrangements prevent fish lying in melt-water containing micro-organisms and the digestive enzymes derived from the stomach and intestines of the fish.

Returnable boxes should be of suitable corrosion-resistant material.

Returnable boxes should be clean to avoid contamination, and strong enough to prevent physical damage to the fish during transit. The boxes should also be large enough to hold sufficient ice to maintain the fish in a chilled condition while they are being transported. Boxes of plastic or light alloy are recommended, as wood cannot be cleaned properly. New developments in some areas include the use of plastic non-returnable liners and returnable outer boxes in alloy materials. Some have built-in melt water collecting compartments so that they can be transported along with other goods, which might otherwise be contaminated by the melt water.

APPENDIX 2

Theoretical calculation of the Specific Ice Melting Rate (K^1) of an insulated container

This is a measure of how effective a container is at preventing the entry of heat from the external environment. It refers to the rate at which ice melts when held inside the container when the outside temperature is 1°C. It should be noted that this does not refer to the amount of ice which melts as fish is cooled which is a completely separate calculation (see Section 3) and is not related to the insulating properties of the container.

Mathematically the Specific Ice Meling Rate (K^1) can be calculated as follows:

$$K^1 = \frac{A.U.}{L}$$

Where A is the area through which heat is transferred, which can be taken as being the internal surface area of the box, including the top and bottom.

U is the overall heat transfer coefficient.

In some cases the box manufacturers may give an average value, otherwise an estimate must be made as shown below.

L is the Latent Heat of Fusion of Ice (which is 334 kJ/kg, see Section 3.1)

Heat Transfer Coefficient (U) is the rate at which heat enters the container per m^2 of surface area per deg. C temperature difference between inside and outside. It therefore depends on the thermal conductivity (K) of the materials which make up the walls of the container, the thickness of this material but also the speed at which heat can pass from the outside environment to the outside wall of the container and similarly from the inside wall to the contents. These last factors are relatively small with well insulated containers and for simplicity can be neglected:

Therefore -

Heat Transfer Coefficient (U) = $\frac{K}{X}$

Where K is the thermal conductivity of the container wall (W/M deg C)

X is the wall thickness (m)

The units of U are W/m^2 deg C.

For a container wall made up of different layers of different materials the approximate Heat Transfer Coefficient of the wall can be calculated from:

$$\frac{1}{U} = \frac{X_1}{K_1} + \frac{X_2}{K_2} + \ldots \frac{X_i}{K_i}$$

APPENDIX 3

Practical assessment of the thermal properties of a container

Lupin (1986) has described a practical method of measuring the melting rate of ice kept in a container. This method consists of weighing the boxes (e.g., using a spring balance or platform scales) and monitoring the external temperature at intervals so that an average temperature can be estimated (a maximum-minimum thermometer can be also utilized). For containers which allow melt water to drain away the weight can simply be measured at intervals to monitor the rate at which ice put into the container melts. The weight loss (i.e. mass of ice melted) should be plotted against time on a graph. This should give a more or less straight line graph (this will depend on the variability of the external temperature) as shown in Figure 17.

This value is the rate at which ice melts at the particular ambient temperature. By dividing this figure by the ambient temperature (which equals the temperature difference across the walls of the container as the ice inside is at 0°C) then the Specific Ice Melting Rate (K^1) will be obtained. Should the heat transfer coefficient (U) also be required this can be calculated by rearranging and solving the equation given in Appendix 2.

Hence $$U = \frac{K^1 . L}{A}$$

where L is the Latent Heat of Fusion of Ice (334 kJ/kg)

A is the area through which heat is transferred

For containers where the melt water does not drain away it is not possible to monitor the rate at which ice melts by weight loss. It is best to see how long it takes for <u>all</u> of a known weight of ice to just melt (completely). Repeatedly opening the container to make observations will allow warm air to enter and thus increase the rate of heat entry so ideally the number of observations should be limited to the minimum necessary to observe the melting of the final portion of ice. Therefore it may take several trials to obtain reliable data.

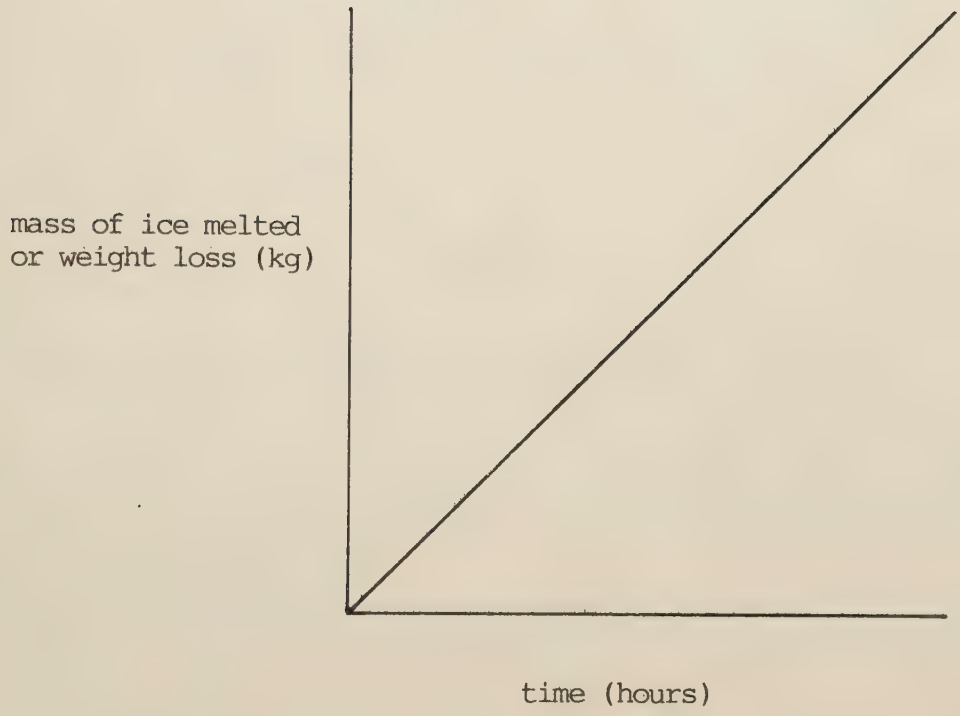

Figure 17 Weight loss as ice melt water drains from a container

Treatment of the data is similar to the above -

$$K_1 = \frac{W_1}{t.T_E}$$

Where W_1 is the weight of ice melted (kg)

t is the time taken for the ice to melt (h)

T_E is the external temperature (^oC)

APPENDIX 4

Construction of on-board insulated fish containers for pirogues (canoes)

(Source: Coackley and Karnicki, 1984)

1. Construction of the containers

1.1 General characteristics

-100mm thickness of high density polyurethane foam with 1 layer of resin and 450g/m^2 density fibre glass matting to form the walls and structure.

- capacity 0.9 - 1.3 tonnes of fish
- weight of container 200kg (with 2 hatches), 270kg (with 3 hatches)
- containers can be shaped to fit into canoe and are removable.

1.2 Materials and tools required

TABLE 13

Materials required for constructing 2-hatch and 3-hatch containers

Material	Quantities required	
	2 - hatch	3 - hatch
Polyurethane foam sheeting, sheets 1.9m x 0.9m, 100mm thick	8.5 sheets	11 sheets
Polyester resin (peroxide catalyst and cobalt accelerator as required)	75 kg	100 kg
Fibre glass mat, 450g/m^2	34m^2	45m^2
PVC tube	0.6m	0.6m
12mm marine plywood	3 sheets	4 sheets
18mm marine plywood	2 sheets	3 sheets
Screws	25	20
Nails	2 kg	3 kg
Hard wood (cross section 230mm x 20mm)	15m	24m
Soft wood (cross section 230mm x 20mm)	35m	40m
Paint	3 l	3 l
Rope	1m	1m

The estimated cost of materials required to make the containers in Senegal in January 1984 was US $800 for the 2-hatch container, US $1,050 for the 3-hatch container.

Some woodworking tools are required such as

- grinder (preferably electric)
- hammer
- wood saw (an electric circular saw would be useful)
- old saw blades for scraping
- tape measure
- marking pen
- modelling knife (Stanley knife or equivalent)
- paint brushes
- wood plane 80mm
- laminating roller
- measuring tube for catalyst
- carpenter's square
- hole saw
- mixing/cleaning bucket

1.3 Container construction

1.3.1 General comments

The work needs to be done or supervised by someone familiar with handling fibre glass and resins as both can be dangerous in unskilled hands. The work may best be done in a boatyard or car body repair workshop where these materials are used.

Fibre glass is inert but can cause irritation to the skin if it comes into contact. it is best handled using rubber gloves. Polyester resin has a storage life of 3-6 months if kept cool in sealed drums. Before use it must be mixed thoroughly with a cobalt accelerator. It is often possible to buy pre-accelerated resin and this is generally preferable.

Just before use the peroxide catalyst must be mixed with the accelerated resin. The catalyst is highly corrosive, poisonous and inflammable. It must be stored securely in plastic containers and CONTACT WITH THE SKIN MUST BE AVOIDED. Wash hands in water immediately if any is spilled on them. THE CATALYST MUST NEVER BE MIXED DIRECTLY WITH THE ACCELERATOR: the mixture can cause explosions.

The polyurethane sheeting must be of high density to give a stronger structure. The size selected was simply the largest size available.

1.3.2 Container construction

The containers were designed to fit into the typical long, narrow pirogues (canoes) used for fishing in Senegal. They have an almost triangular (rather than rectangular) hull cross section. The containers were designed to be supported on the bottom of the boat and maximise the use of the cargo space and so had the shape shown in Figure 18.

Firstly the sheets of polyurethane foam must be prepared for use. The shiny surfaces left by the moulding of the material must be scraped with saws to expose the rough cellular material. The panels must then be prepared to the correct size. Both end panels were cut from one sheet, side and bottom panels are either $1\frac{1}{2}$ sheets (2 hatch-container) or 2 sheets (3 hatch-container). Sheets can be joined together by squaring up the sheet edges on a band or circular saw and applying a ployester resin to which more than the usual amount of catalyst has been added. The sheets are then pushed together, pegged with small wooden pegs and left lying on scrap cardboard on a flat floor. After the sheets have set the pegs can be snapped off and the holes filled with resin. It is important to design the container such that the joins in the different sheets (ie sides, bottom and top) overlap with solid sheeting so that there is not a continuous join running right around the container at a single point. The joins between sheets are inevitably weak points in the structure.
The bottom panel must have slanted side edges cut using a suitably made template so that it can be joined correctly to the sides. The top sheet must have parts cut out for the hatches, the cut out portions being retained to insulate the hatch covers (see also Figure 19). End sheets have drainage holes cut at each of the bottom corners.

Next the panels are assembled using the same technique used for joining the polyurethane sheets. The side, end and base panels are fixed together. The unit and the top are then prepared further before bonding them together. Firstly any rough areas must be smoothed down and the surfaces cleaned of particles. The bottom unit and top are then coated in fibre-glass and resin (FRP) on both inner and outer surfaces. Join lines on the top need to be reinforced with an extra layer of mat.

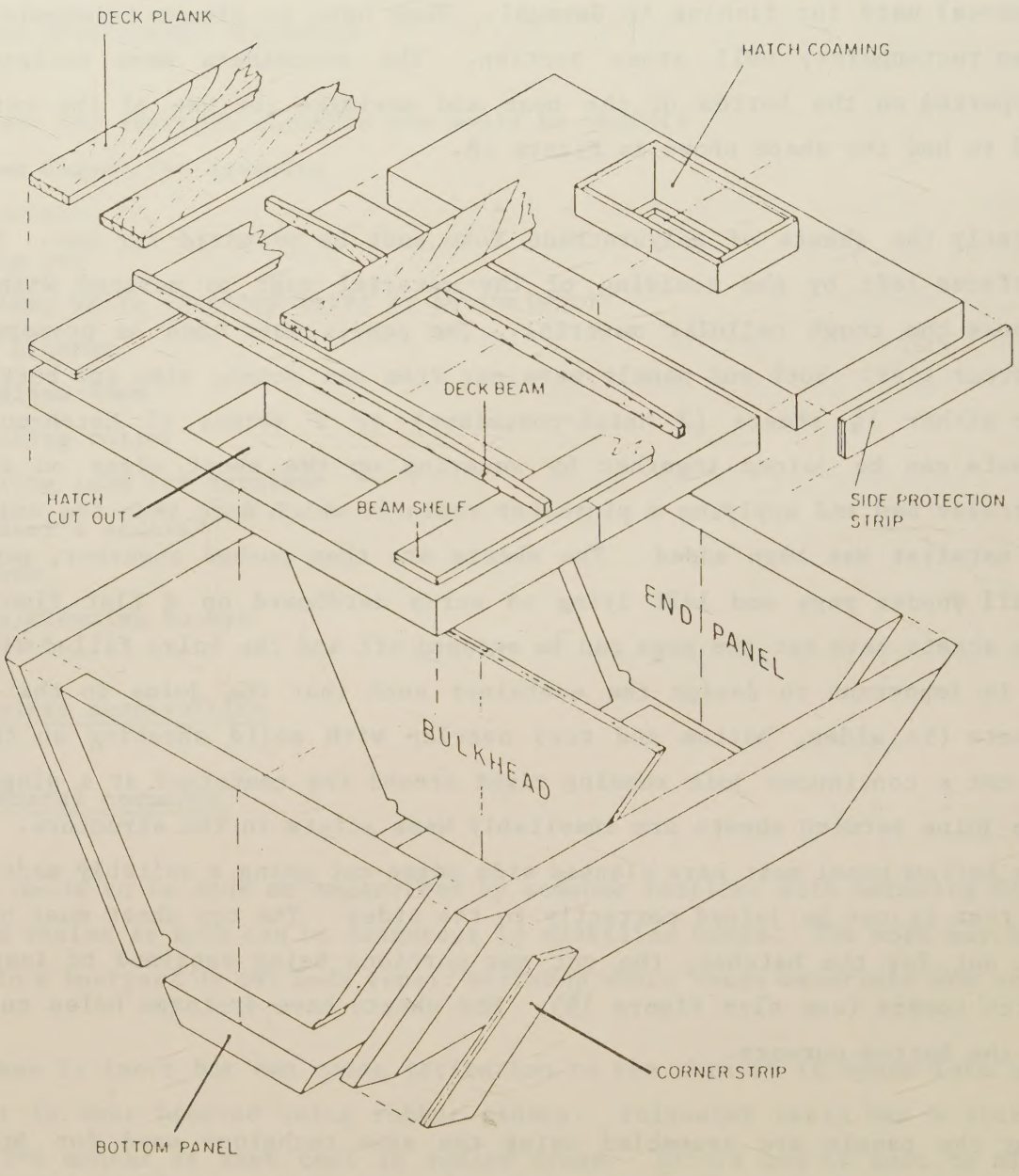

Figure 18 Insulated container constructed by Coakley and Karnicki (1984)

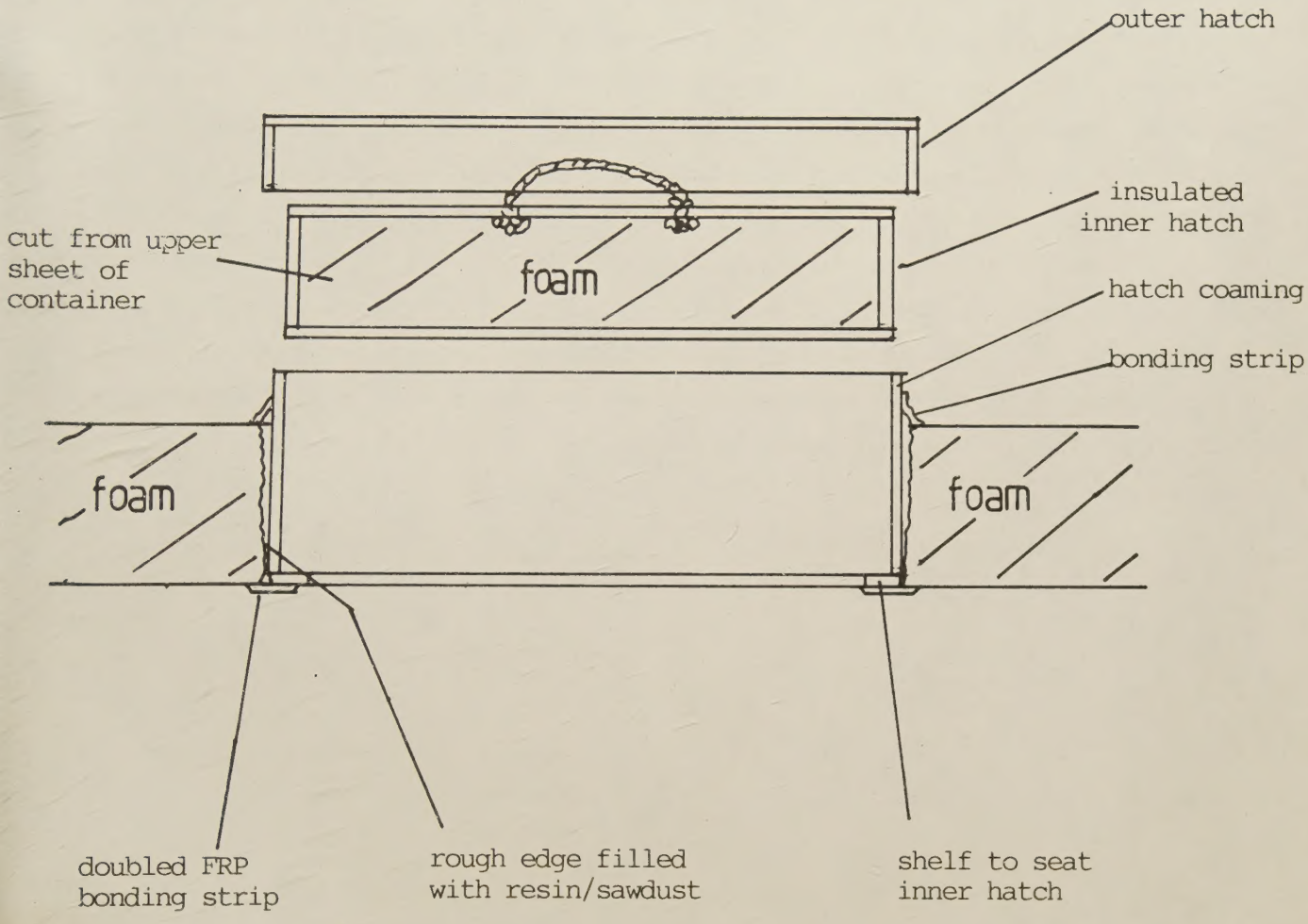

Figure 19 Hatch for Coakley and Karnicki (1984) container

The hatch surround (coaming) should then be installed. These are made of marine plywood which is bonded into the holes in the polyurethane sheeting with strips of fibre-glass and resin at the top and bottom. A marine plywood bulkhead is also fitted inside the base presumably using the same technique, although Coackley and Karnicki (1984) are not specific on this point.

The structures should then be checked to ensure they are secure, the foam well covered with resin and that the drain holes are unblocked. The interior should be clean. The top can then be fitted to the base unit using the same technique as before. The top/side and top/end joints should be trimmed to accept the protecting wood strips, deck beam shelf and the subsequent FRP bonding layer. Container corners also need to be trimmed back to accept protecting ply strips. The deck beams can then be cut and screwed onto the beam shelf (illustrated in Figure 18) and the wooden deck planking nailed to them. The bottom is protected by bonding on wooden skids and covering them in resin. The outside is then smoothed off, the container checked for leaks (which can be repaired with resin perhaps with polyurethane scraps) and the hatch covers made as shown in Figure 19. The hatches and hatch surrounds are then painted white.